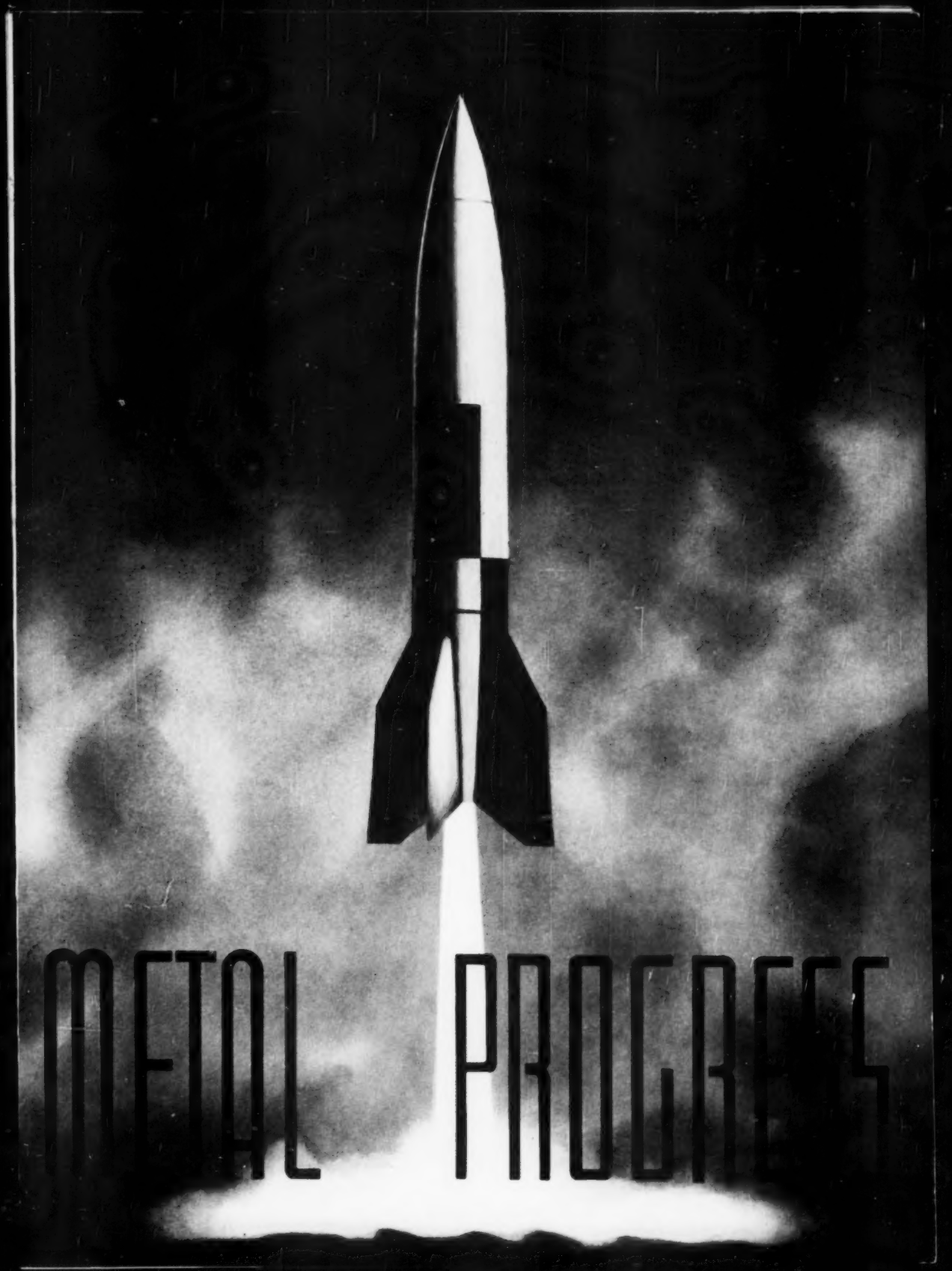
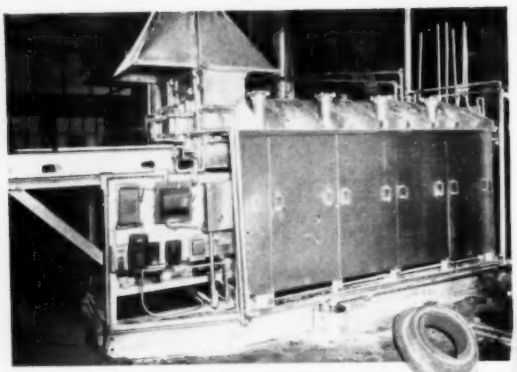

METAL PROGRESS

New Profits in Production Forqinq!



'Surface' HIGH SPEED BILLET HEATING WITH GAS OR OIL

*Outstanding IN EVERY WAY

* **LENGHTENS DIE LIFE** . . . because of extremely thin scale, uniformity of billet temperatures with automatic cycles and apparent improvement in plasticity due to rapid heating.

* **SAVES LABOR** . . . due to automatic handling and increased production rates. Also greater utilization of press capacity.

* **IMPROVES WORKING CONDITIONS** . . . promotes clean and neat surroundings. Operators do not face or work in high heat.

* **SAVES FLOOR SPACE** . . . one compact furnace unit occupies one-fourth to one-third in floor space as compared with conventional methods.

* **EQUIPMENT LOW COST** . . . the initial or equipment cost of complete furnaces of this type ranges from 30 to 75 percent less, as compared with other methods.

* **SAVES METAL** . . . due to decrease in scale.

* **METALLURGICAL IMPROVEMENTS**...decarburization and grain growth are retarded.

* **CLEANER FORGED PARTS** . . . reduced cleaning and machining costs for forged parts with less imbedded scale in the surface of the forging.

* **PRESS OR HAMMER RATES INCREASED** . . . it is possible to operate at rated press or hammer capacity.

* **LOW FUEL COST PER TON HEATED** . . . in one instance where the same forging was heated by three heating mediums, the fuel costs showed high speed gas to be almost 50 percent less.

'Surface' has developed a new combustion system and furnace design to give fast, high temperature heating for production forging. In every application of 'Surface' High Speed Furnaces they have excelled other methods *in every way*. Now, without added floor space you can increase production...better the quality of product and work...improve working conditions and *Save Money*.



NEW...ask for it!

More descriptive data on the high speed combustion system, the furnace unit, applications, and comparative costs. Write for your copy Bulletin SC-144 today.

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES

Why 10¢?



HARDEN IT for 1¢

One 100 KW, 10,000 cycle TOCCO machine does 139 different production hardening jobs at Lima-Hamilton Corp., Lima, Ohio.

with TOCCO* Induction Heating

Progressive engineers at Lima-Hamilton Corporation recently adopted TOCCO Induction Heating for the hardening of bearing areas on this slide pin used in famous Lima Power Shovels. Your part may be very different but if it has to be hardened, soldered, brazed, annealed or forged TOCCO probably can cut your costs and improve your products, too.

CUTS COSTS Formerly this pin was carburized and hardened all over by conventional heating methods. Distortion was such that each part had to be straightened and then centerless ground to close limits. Rejects often ran 25% to 30%. TOCCO heats just the bearing areas that require hardening—result, no distortion, no final grinding, no rejects and 9¢ saved on each part. Production is 410 pieces per hour.

VERSATILITY, TOO In addition to the pin shown above, Lima hardens 138 other parts ranging from small screws to large gears—all on the same TOCCO machine. Between production hardening jobs, the machine is used for brazing carbide tips on cutting tools—some 10,000 during 1948. TOCCO engineers will gladly survey your plant to determine where TOCCO can cut your costs, speed-up your production, without obligation, of course.

THE OHIO CRANKSHAFT COMPANY



TOCCO

Mail Coupon Today

NEW **FREE** BULLETIN

THE OHIO CRANKSHAFT CO.
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Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating".

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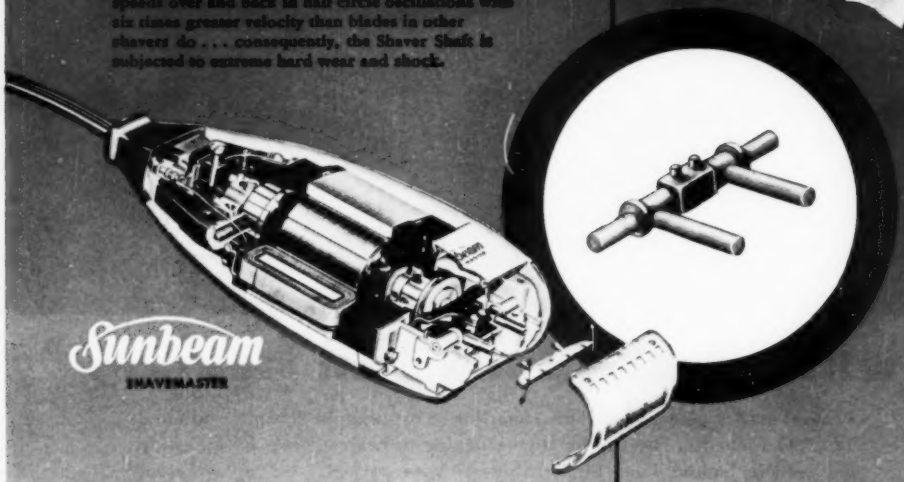
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here's how Microcastings

make possible faster, smoother shaves

The MICROCAST Shaver Shaft is a vital part in the shaving mechanism of the Sunbeam Shavemaster. This device controls a special cutter which speeds over and back in half circle oscillations with six times greater velocity than blades in other shavers do . . . consequently, the Shaver Shaft is subjected to extreme hard wear and shock.





Sunbeam SHAVEMASTER

MICROCASTING SAVES 3 PARTS

The Shaver Shaft is cast of straight chrome steel eliminating expensive machining costs. Formerly this shaft consisted of three parts . . . *another production case history in which Austenal* MICROCASTINGS *are serving manufacturers by saving them time and money and improving performance of their products.*

Precision Castings From High Melting Point Alloys That Require Little or No Machining—The MICROCAST process offers a flexibility in meeting design problems not possible in the past without pyramiding costs. Small parts of intricate shape can now be specified in a whole new range of high melting point alloys which offer advantages of extreme resistance to heat, wear and corrosion.



NEW CATALOG AVAILABLE

A copy of the new 16 page book, "New Horizons with Microcasting," is yours upon request. It is the most complete report ever published on the subject of the MICROCAST process originated by Austenal Laboratories, Inc. See our catalog in Sweet's File for Product Designers.

MICROCAST PRECISION CASTINGS PROCESS

The name "MICROCAST" is a registered trademark of the Austenal Laboratories, Inc.

MICRO CAST

MICROCAST DIVISION
AUSTENAL LABORATORIES, INC.
224 East 39th Street • New York 16, New York
715 East 69th Place • Chicago 37, Illinois

Steel Mill Boosts Quality and Output With Help of Micromax Pyrometers

How can a steel mill engineer invest his Company's thousands of pyrometer dollars, so as to get the greatest dividends from the millions invested in manufacturing equipment?

And how can he surely make his control systems help to the utmost in holding quality, cutting costs and raising output?

Following are some of the answers, taken from a mill which turns out a wide variety of products and where the right temperature control by means of Micromax instruments has proved its worth in many processes.

Continuous Tinning (See Fig. 1)

Uniform temperature in the tin pot helps to maintain uniform rate of deposit, minimum dross formation and maximum production.

Hot Dip Galvanizing (See Fig. 2)

Here Micromax Electric Control throttles fuel to the burners. Accurate temperature control means uniform coating, lower consumption of zinc, less maintenance, and less "down time" for drossing.

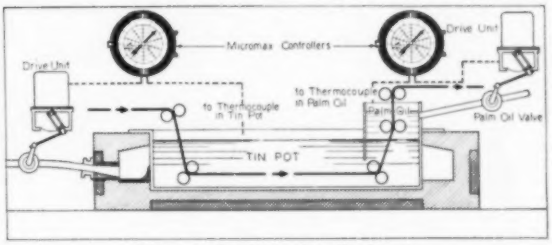


Figure 1. Continuous hot-dip tin pot.

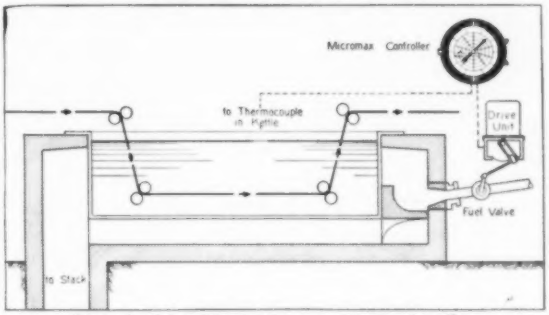


Figure 2. Galvanizing kettle, on continuous sheet line.

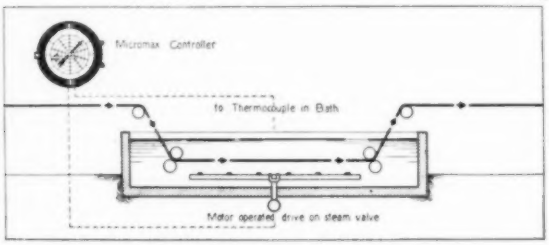


Figure 3. Steam-heated pickling baths.

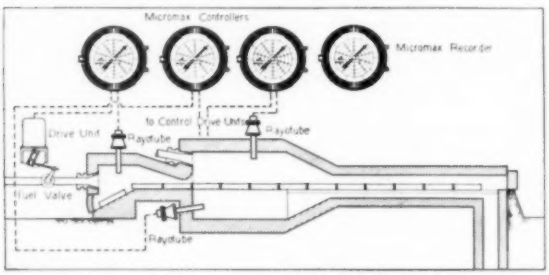


Figure 4. Slab heating furnace. A fourth Rayotube near the one shown in the lower zone detects slab temperature and reports it to the Pyrometer at top right.

Continuous Pickling Baths (See Fig. 3)

Here the ability of Micromax to stay on the job continuously, and with low maintenance, helps to keep the process operating at top efficiency a maximum percentage of the time.

Slab Heating Furnace (See Fig. 4)

This illustrates the application of Micromax Rayotube Pyrometers to a complex temperature control problem.

Complete temperature control helps the furnace to perform efficiently its functions of bringing the slabs back to rolling temperature, holding them at temperature until the mill is ready to receive them, and finally delivering the slabs at the right time properly conditioned for efficient rolling.

An L&N field engineer is always ready to discuss any temperature control problem with you. Or if a description of the equipment will meet your needs, we'll be glad to send catalogs on request. Address Leeds & Northrup Co., 4927 Stenton Avenue, Philadelphia 44, Pa.

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LEEDS & NORTHRUP CO.

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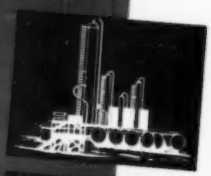
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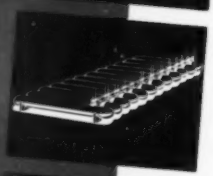
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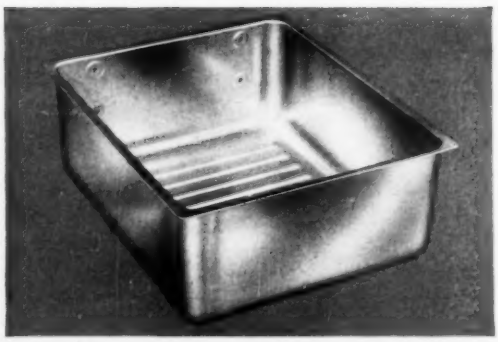
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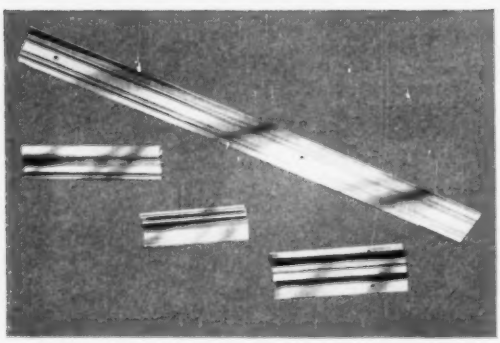
Announcing













VERSATILITY of the new Kaiser Aluminum 150S alloy is illustrated by the wide variety of fabrication methods necessary to produce the items shown here. Each of these products has been *improved* with 150S. Each is an excellent application of 150S.

150S

A new Kaiser Aluminum Alloy to improve your product

After two years of continuous research and development, Permanente Metals announces a versatile new alloy of Kaiser Aluminum: 150S.

Meeting a long-felt, industry-wide need, it is the first *general purpose specification* alloy to be introduced in 20 years. Its combination of yield strength and workability makes it stronger than 3S, more workable than 52S—giving it properties intermediate between the two.

Most drawing, forming, beading and joining operations can be done satisfactorily with 150S.

Inherently a fine grain alloy, it can offer satin anodized finishes that are silvery white in color. Its hard surface resists dents and scratches, reducing in-plant scrap. And it has corrosion resistant properties similar to 52S.

You may be one of the hundreds of manufacturers who will now be able to cut material costs and improve products because of the unique combination of advantages offered by 150S.

Good physical properties
Very fine grain structure
Good workability
Good welding and brazing properties
Exceptional finishing properties
Excellent corrosion resistance

If you are now using 52S or 3S, you may be able to reduce your material costs or improve your product—or both—with this versatile new alloy. For more information, contact the nearest Permanente Products' sales office or distributor.

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When one day during World War II a truck driver delivered at the Ft. Wayne Works 25,000 motor shafts, mistakenly intermixed, he started G-E engineers on the development of an important new instrument for industry.

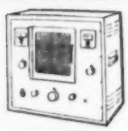
To separate the shafts, Ft. Wayne engineers rigged up an oscillator, multi-winding transformer, amplifier, and an oscilloscope, and then identified each shaft by comparing its wave pattern with the known wave patterns of the different kinds of steel used. Realizing the importance to industry of such equipment, G-E engineers developed a compact comparator for both ferrous and nonferrous metals.

Cutting Costs This instrument helps you cut costs by enabling you to separate or to identify metals quickly. For example, stock-room clerks use the instrument to separate machinable parts of cold-rolled steel from nonmachinable parts made from stainless steel. This reduces cutting-tool losses.

Maintaining Quality Control To help maintain the high quality of your product, use the comparator to measure the depth of case hardening, to determine changes in plating thickness, and to assure the use of specified metals.

A G-E Instrument for Your Problem G-E engineers may be able to help you solve your measuring or testing problems by recommending one of the many available G-E instruments. Your problem, if it is common to industry, may even justify developing a new instrument. Write today for information. Apparatus Department, General Electric Company, Schenectady, N. Y.

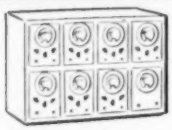
General Electric testing and measuring equipments for nearly every industrial process



Coil Testing



Time, Speed and Torque



Force, Strain and Thickness Gages

To Cut Costs in Your Developmental Work

. . . use G-E fatigue tester to study fatigue limit and failure of metals and plastics

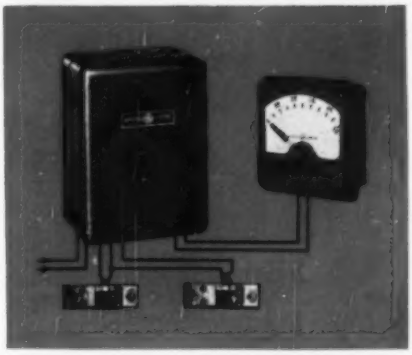


Equipment designers and metallurgists can save time—and money—by using the G-E fatigue tester to determine the fatigue limit of different alloys or plastics.

By fatiguing materials at resonant frequency, the G-E instrument reduces the amount of time required for each test. Because the instrument, which uses air pressure to vibrate the material specimen or finished part, has no moving parts, maintenance expense is negligible. Furthermore, you can test both standard specimens and odd-shaped parts, such as turbine buckets.Write for GEA-4652.

To Increase Life of Your Equipment

. . . check for excessive strain with G-E magnetic strain gage



You can safeguard the life of construction, industrial, and transportation equipment by using the G-E magnetic strain gage to test shovel and crane structures, punch presses, dies, test-stands, tanks, railroad tracks, locomotive trucks, bridges, and truck frames. Easily attached or removed from the equipment under test, the strain gage is protected against normal vibration or shock. No amplifier is required.

This gage equipment measures either slowly varying or rapidly varying strains. A pointer on an easy-to-read scale indicates the amount of stress. Write for GEA-3673.

To Cut Costs in Specifying and Inspecting Finishes

. . . use the New G-E roughness scales

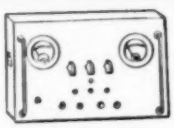


The 24 sample surfaces of the scales are divided into ten groups representing ten degrees of surface roughness. Some groups have several machining operations represented. Use of the scales cuts production costs three ways—

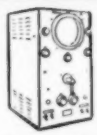
Engineers and designers save time because they need only to refer to the scales to specify finishes. Inspectors can handle additional work because they can use sight and touch to compare quickly the finish on a machined part with specified finishes. Machinists turn out extra work because they can avoid making unnecessarily fine finishes; reduce spoilage because they can avoid making too-rough finishes. Write for GEC-311.



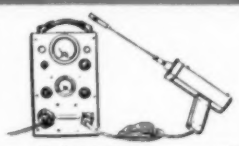
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Spline Shaft Hardening at Maytag Company plant, Newton, Iowa. Diameter, .75". Length over-all, 8.5". Length of spline, 2". Steel, C-1144. Surface hardness, 57-60 Rc. Case depth, .027"-.035". Equipment, Westinghouse 20-kw RF Generator, Type C. Production, 580 per hour.



Straight Shaft Hardening with Westinghouse 20-kw RF Generator, Type B, at Maytag Company. Diameter, .685". Length over-all, 6.75". Steel, C-1144. Surface hardness, 57-60 Rc. Case depth, .027"-.035". Production, 600 per hour.

Westinghouse

RF HEATING

LIKE *Maytag*...

YOU can profit with WESTINGHOUSE RF HEATING



20 Kw Westinghouse RF Generators cut production costs at Maytag Company... Paid for themselves in ONLY 3 MONTHS

Take a tip from Maytag's experience with profitable RF Heating. Investigate the possibilities of installing this time and money-saving equipment in your production line.

Compare these results with RF Heating at Maytag:

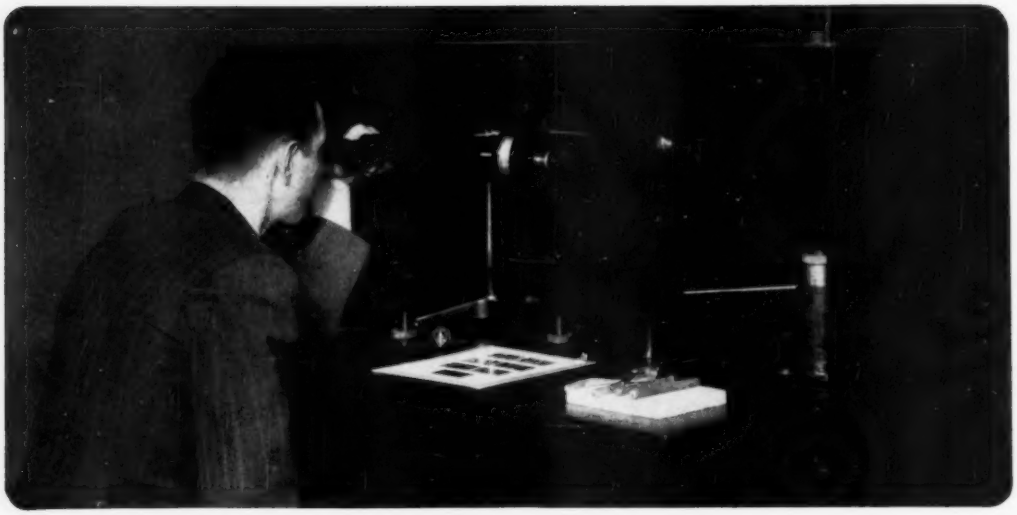
Engineering-wise—it's BETTER . . . Distortion has been *eliminated*. With former heating methods, distortion of approximately .012" was experienced. With RF Heating it is consistently .001" or less. Straightening operations are eliminated; all shafts are uniform. In addition, no scale is formed with the RF Heating process.

Production-wise—it's FASTER . . . Batches of 400 shafts which formerly required 2½ hours of furnace treating are now handled in *less than 1 hour* on each 20-kw RF Generator with continuous work-handling equipment.

Management-wise—it's CHEAPER . . . Shaft straightening and de-scaling have been eliminated. Primary power costs are *down* 48%. Rejects are a thing of the past.

Why not get more out of your production line? From the full line of Westinghouse RF Generators there's a generator that's *exactly* right for your job.

Call your local Westinghouse representative, or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-02194



HARSHAW *Spectroscopic* METAL ANALYZER

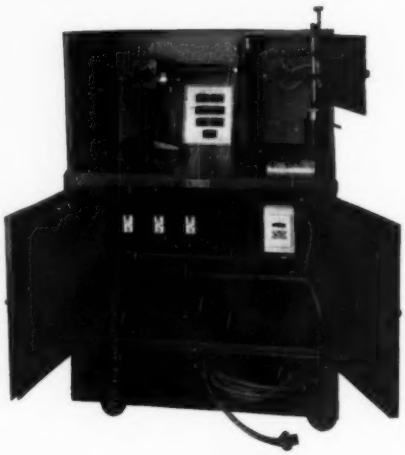
The Harshaw Spectroscopic Metal Analyzer is now being used for all types of ferrous and non-ferrous metal sorting and identification. It is also used for quantitative analyses. For example, the quantitative analysis of magnesium in aluminum alloys can be carried out in one minute with an accuracy of 5% of the amount present.

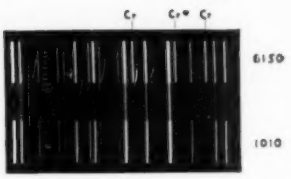
The unit consists of a fixed deviation glass prism spectrometer mounted on a portable cabinet. A 3-prong cable is provided for plugging into 220 volts D.C. The third connection should be grounded. Resistances are provided to give a selection of amperages between 4 and 10 to provide for different size specimens. The current is turned on by the switch conveniently located on the table top. A safety switch on the door jam of the shock-proof arc house disengages the bipolar relay as soon as the arc house door is opened. The arc stand provides for irregular sized specimens and is adjustable in all directions from outside the box. An automatic arc striker is included.

The spectrometer is calibrated for the following elements:

Copper	**Vanadium**	**Manganese**	**Titanium**
Chromium	**Molybdenum**	**Cobalt**	**Tungsten**
Lead	**Nickel**	**Columbium**	**Zirconium**

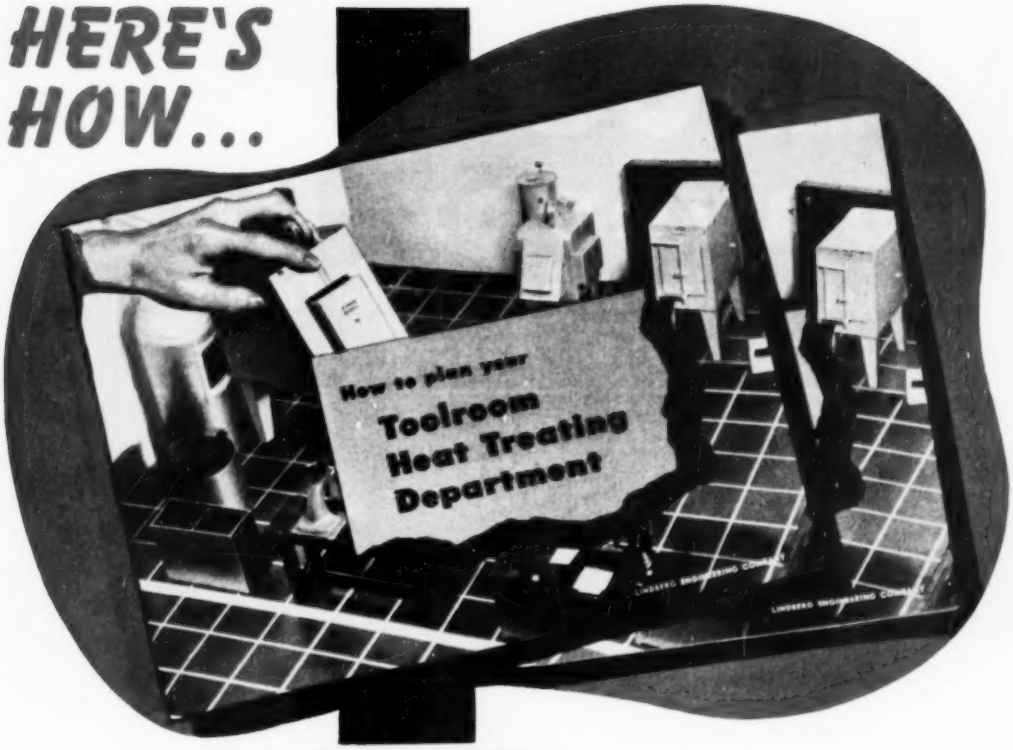
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TO PLAN YOUR
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Published to assist those planning new or expanded heat treating departments. It's yours for the asking.

Material contained in this 24 page booklet, prepared by the Lindberg Engineering Company, is based upon years of experience in helping design hundreds of toolrooms . . . plus additional information gained from the 24-hour-a-day operating experiences of the toolroom heat treating department of the Lindberg Steel Treating Company, the world's largest.

It helps arrive at total costs in advance • Shows recommended department layouts • Tells how to select furnaces of proper size • Gives prices of auxiliary equipment such as tongs, quench tanks, straightening presses, hardness testers, work benches, etc. • Contains loose template pages of furnaces, quench tanks, etc. and graph paper . . . a few seconds of scissor work shows you how your department will look.

To get your copy write or call your nearest Lindberg Engineering Company office or the Lindberg home office at 2448 West Hubbard Street, Chicago 12, Illinois.



Other helps for Heat Treaters. "Heat Treating Hints"—a publication covering the practical side of heat treating with strictly "how to do it" articles. Available on request.

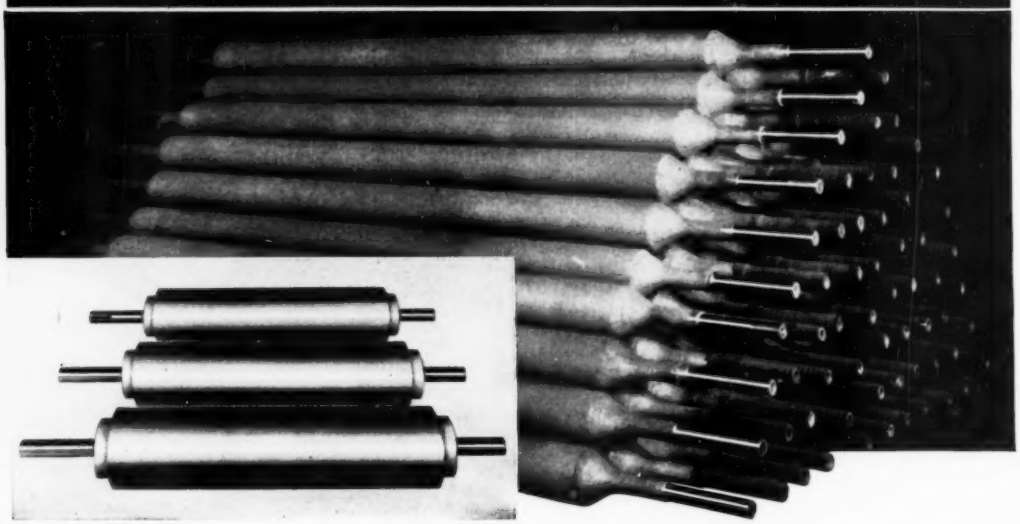
"Heat Treating Hints", two movies, (color and sound) bring to the screen practical articles from the printed "Heat Treating Hints". Ideal for technical associations, plant showings, schools. Write for Bookings.

LINDBERG  FURNACES

MISCO *Centricast* Conveyor Rolls

for Bright Annealing • Normalizing • Heat Treating Furnaces

LIGHT · SOUND · STRONG · ACCURATE



THROUGH the application of our flash welding process to roll construction, mechanical joints have been eliminated in the manufacture of Misco Centricast Conveyor Rolls. No added metal is used at the joints because the end castings and the centrifugally cast mid-section are directly united under pressure at fusing temperature. Misco flash welded joints produce a sound one-piece construction. Misco Centricast Conveyor Rolls can be supplied in many sizes, with smooth cast, rough turned or bright ground finish. Thousands of Misco Centricast Conveyor Rolls are giving dependable service at temperatures up to 2050° F. Misco Centricast Conveyor Rolls will serve you better.

SPECIFY MISCO HEAT RESISTING ALLOYS

• CAST and ROLLED •

For all Heat Treating Equipment

Furnace Parts • Roller Rails • Roller Hearths • Conveyor Rolls • Trays • Retorts Chain • Muffles • Walking Beam Conveyors • Carburizing and Annealing Boxes Dipping Baskets • Cyanide and Lead Pots • Thermocouple Protection Tubes • Pickling Equipment • Centrifugal Castings • Miscellaneous Castings and Rolled Bars • Sheets, Plates, Tubes and Welding Rod for use at high temperature or under corrosive conditions.

ALLOY CASTING DIVISION
Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys

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Buyers everywhere want products that are easier to lift and move. They want products made from Dow

MAGNESIUM

the world's lightest structural metal!



When greater lightness helps sell a product—and it does help sell a good many—sound judgment on the manufacturer's part dictates using the lightest practical metal . . . Magnesium.

Magnesium is the world's lightest structural metal—75% lighter than steel, 33⅓% lighter than aluminum.

If your product is still too heavy, lighten it with the one metal that can do that job best . . . Magnesium. Remarkably strong and easily worked—magnesium will be found surprisingly low in cost compared to the competitive advantages gained. Write us for complete technical information. And don't forget to ask for your free copy of "How Magnesium Pays" a book filled with real case studies of how magnesium is being used profitably in products today.

THE DOW CHEMICAL COMPANY • MIDLAND • MICHIGAN

New York • Boston • Philadelphia • Washington • Cleveland • Detroit • Chicago
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Make your product easier to lift—easier to move—easier to sell—with Magnesium Extrusions

Manufacturers of a wide range of products—ladders, for example—who know how much *cutting dead weight* means to their customers, are using magnesium extrusions. They've found that magnesium extrusions enable them to make their product appreciably lighter, yet retain much needed durability and strength. They've found, too, that Magnesium Extrusions simplify design, fabrication and assembly. Many intricate shapes *can* be extruded in magnesium which can *not* be produced by any other method.



Lighter Products Sell— make your product Magnesium Light!



You have been elected

IT is time to recognize anew the obligations of leadership--the reponsibility that attends your place in the business life of the community.

That there are influences at work right now--every day--attempting to disrupt and destroy the American way of life--has been plainly demonstrated. These forces, disguised though they be, are more active - more determined - more dangerous than ever before.

To save individual liberty and personal freedom--corner-stones of our civilization--may not be easy. As a leader you are called upon continuously to help form and direct a militant public opinion. Only by the united, vigilant efforts of all citizens of good will, those who cherish our principles of government and our ideals, will we maintain our invaluable heritage of liberty, justice and freedom.

The Youngstown Sheet and Tube Company

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MANUFACTURERS OF CARBON, ALLOY AND YOLOY STEELS

ELECTROLYTIC TIN PLATE - COKE TIN PLATE - WIRE - COLD FINISHED CARBON AND ALLOY BARS - PIPE AND TUBULAR PRODUCTS - CONDUIT - RODS - SHEETS - PLATES - BARS - RAILROAD TRACK SPIKES.

Bulletin on SUPER REFRACTORIES by CARBORUNDUM

TRADE MARK

NO. 4 JULY, 1949

How To Use Super Refractories

In most installations, there is at least one area where refractory life is curtailed by unusual conditions. Perhaps only a few brick—a tile or two—may be involved. Nevertheless, their replacement means furnace shutdowns . . . production delays . . . increased maintenance. In such cases, Super Refractories by Carborundum can prove to be profitable. They are better fitted inherently to withstand rigorous service. Specialized characteristics enable them to lick localized trouble spots. Improved overall refractories performance eliminates frequent, expensive outages. Definite savings result from the wise, even though limited, use of these super refractories with other less costly refractories.

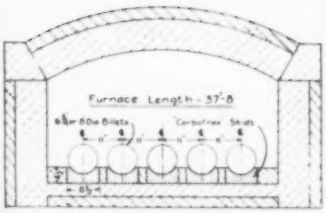
More extensive use of Super Refractories by Carborundum may be indicated for some jobs. Possibly top performance will be insured only through their full utility. Numerous accepted processes, involving large scale usage, are practical and economical simply because of the well-considered application of these products.

Super Refractories by Carborundum are produced from several different basic materials. Each type is available in many varieties to better meet a wide range of service requirements. For best utilization, it is important to consult with our refractories engineers. Their recommendations are based on broad experience.

Physical Properties of Super Refractories by CARBORUNDUM

TRADE MARK

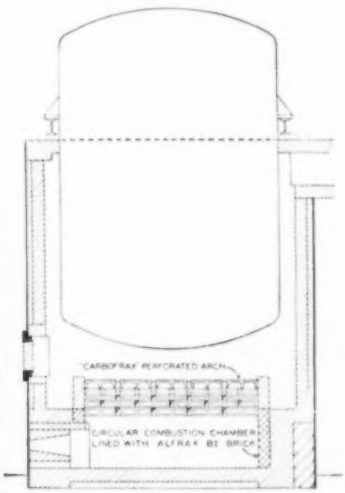
	CARBOFRAX	MULLFRAX	MULLFRAX S	ALFRAX K	ALFRAX B	ALFRAX BI
Heat Conductivity at 2200°F. in BTU/hr. sq. ft. and °F./in. of thickness	109 BTU	16 BTU	9 BTU	24 BTU	12 BTU	7 BTU
REFRACTORINESS PCE-CONE	37-40	38-39	37-38	37-39	39-40	38-39
SPALLING RESISTANCE	High	High	High	Good	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION (25°—1400° C.)	.0000044	.0000059	.0000069	.0000074	.0000086	.0000086
MODULUS OF RUPTURE @ 2460° F. PSI	800-3125	100-250	175-475	100-1050	100-225	50-100
WEIGHT 9 IN. STRAIGHT	9.25 lbs.	9 lbs.	8 lbs.	10.1 lbs.	7.25 lbs.	4.8 lbs.



CARBOFRAX Skid Rail Life Increased From Weeks To Years

This extrusion-mill furnace is now equipped with CARBOFRAX silicon carbide skid rails. Formerly, a chrome hearth was used in the hot zone and alloy rails in cooler sections. This chrome-alloy combination required expensive maintenance and replacement every 2 to 5 weeks. In addition, pile-ups and wrecks were caused by rail warpage.

With the installation of CARBOFRAX skid rails, 3 years life is obtained before replacement is necessary. Frequent furnace outages are eliminated. Production is increased. Operating costs have dropped. Rails remain true—without warpage. There are no wrecks or pile-ups. Because frictional resistance is greatly reduced, brass billets are slid through the furnace more easily.



Set Kettle Utilizes Job-Fitted Super Refractories

Here is a case where judicious use of two different refractory materials resulted in extended service life of both the set kettle and setting. In addition, simplified and accurate temperature

"Carborundum," "Carbofrax," "Mullfrax," "Silfrax," "Alfrax" are registered trademarks which indicate manufacture by The Carborundum Company

Address all correspondence to: Dept. J-79, THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

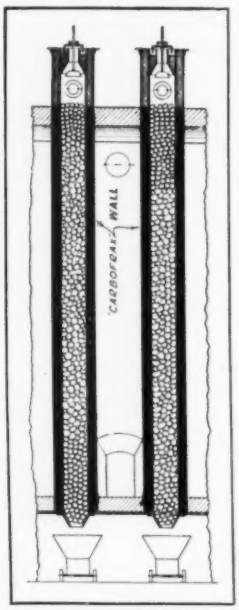
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control has been achieved along with lower fuel costs.

Because of their high mechanical strength and thermal conductivity, CARBOFRAX silicon carbide shapes were selected for the arch. More rapid and even radiation of heat to the kettle is provided. Lower temperatures are required in the combustion chamber. Moreover, remarkable resistance to spalling and cracking provides "insurance" against service interruptions.

Light-weight ALFRAX BI fused alumina insulating brick, applied to the combustion chamber to reduce heat storage in the setting, provides more accurate temperature control.



CARBOFRAX Vertical Retorts Open Door to New Processes

Several newly developed chemical and metallurgical processes are now not only possible but also economical through the use of CARBOFRAX refractories as the structural material for forming retorts. Restricting limitations that existed formerly are removed. Because of their high thermal conductivity, only moderate thermal gradients are required to transmit heat rapidly through retort walls. Close temperature control is provided. Consequently, combustion chamber temperatures are lower, fuel efficiency is improved, and refractory difficulties are minimized. Great strength at high temperatures plus mechanical and flame abrasion add long uninterrupted service to the other advantages of a CARBOFRAX vertical retort.



Operator Summarizes Advantages of CARBOFRAX Setters

Several important advantages of using CARBOFRAX setters are concisely summarized in this report from a producer of sanitary ware:

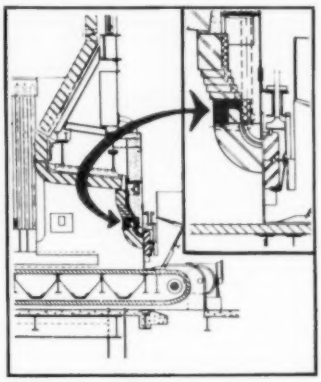
"Since going into operation (over 6 mos.) there have been absolutely no losses in tank or bowl setters due to firing cracks. All losses have been due to mechanical handling or dropping. There has been no sagging, warping, deformation or growth in size although the setters are supported only on the ends by firebrick and have no continuous support underneath."

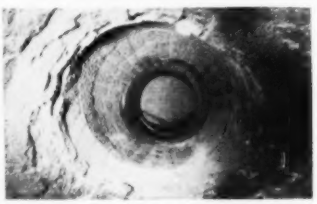
Operating data: Firing Temperature—Cone 11. Cycle—33½ to 36 hours.

Judicious Use of Super Refractories Licks a Trouble Spot

Three courses of CARBOFRAX silicon carbide brick were all that were required to solve the troublesome problem of uneven secondary air distribution in this boiler furnace.

The trouble was traced to fingers of slag which formed above the air nozzles in the front and rear walls. This slag deflected the air streams enough to disturb secondary air distribution. Fuel burned unevenly. Shut-downs were frequent and fuel efficiency was lowered. When CARBOFRAX brick were installed just above the air jets, the trouble was eliminated. Slag can not anchor on the smooth, hard, dense surface of this clinker-resistant Super Refractory.





This Flue-Connector Lining Has Seen 10,000 Hours of Service

There is a distinct lack of carbon build-up in this unretouched photo of a flue connector lining after 10,000 hours of service. The hard, dense, smooth surface of CARBOFRAX lining provides no anchorage for these obstructions. Equally important is the freedom from erosion despite the fact that the lining has been subjected to the beating of millions of abrasives particles travelling at terrific velocity. Cleaning is minimized, down-time for repairs is reduced.

A complete file of informative literature covering super refractories is available through The Carborundum Company. There are facts and figures on installations in specific fields. To obtain copies of reports, booklets and catalogs of particular interest is a simple matter. Merely select from the list printed here. Copies will be sent you at once. No obligation, of course.

Super Refractories by CARBORUNDUM (general catalog)

Super Refractories for the Ceramic Industry

Super Refractories for the Process Industry

Super Refractories for Boiler Furnaces

Super Refractories for Heat Treatment Furnaces

Super Refractories for Gas Generators

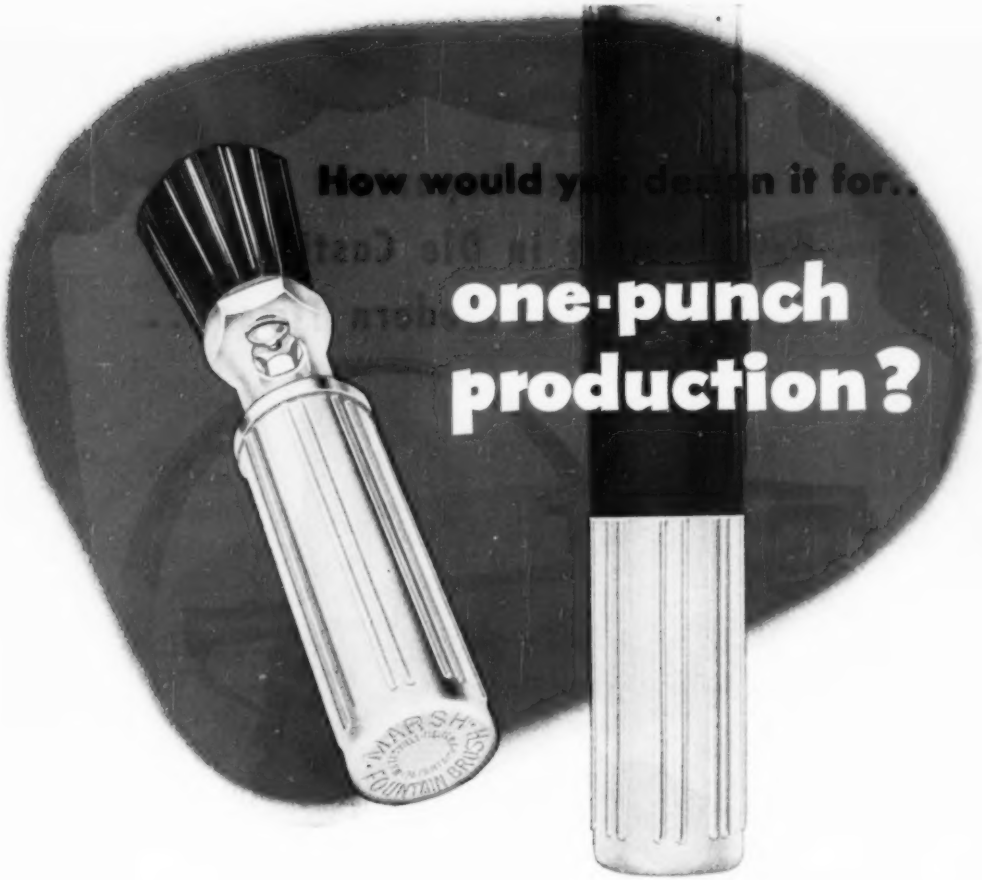
The FRAX Line of Cements

CARBOFRAX Refractory Skid Rails

Bulletins Nos. 1, 2, 3 on Underdrain Systems and Diffuser Media

Dept. No. J-79

THE CARBORUNDUM COMPANY
Refractories Division
PERTH AMBOY, NEW JERSEY



Alcoa's amazing Impact Extrusion process knocked out this marking brush handle and inkwell with one punch! Brush head is threaded directly into the impact-extruded handle.

Costs for Alcoa Impact Extrusions are often substantially below stamping, drawing, spinning and machining for the same shape. Parts may be assembled as delivered, or finished by all commercial finishes plus lustrous Alumilite* exclusive with aluminum.

Get the whole story on how Alcoa's new process can lower your costs while giving you all of aluminum's sales advantages—light weight, strength, corrosion resistance, handsome appearance. Write for your copy of booklet shown, "Alcoa Aluminum Impact Extrusions", or call your nearby Alcoa sales office. ALUMINUM COMPANY OF AMERICA, 2101G Gulf Bldg., Pittsburgh 19, Pennsylvania.

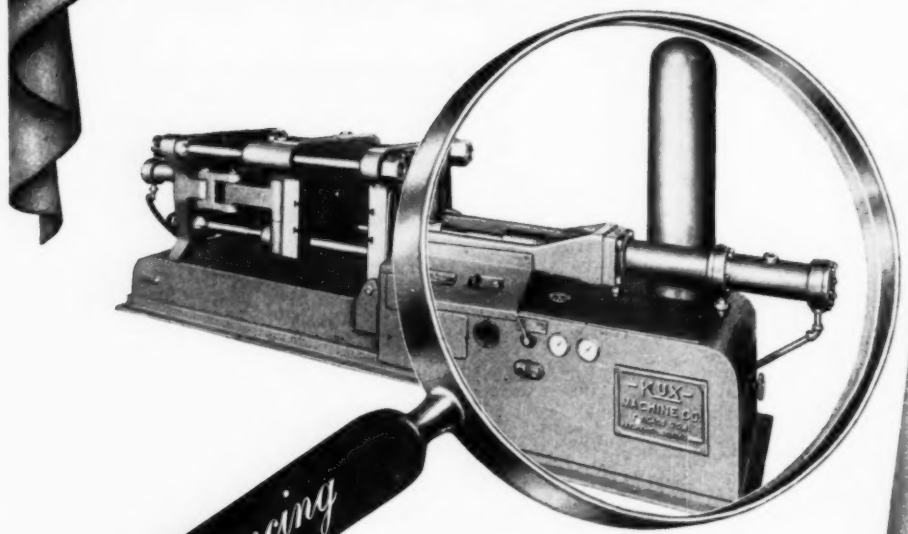


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ALCOA *Aluminum* **IMPACT EXTRUSIONS**

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the most important development in Die Casting Technique of Modern Times...



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the revolutionary **new**

KUX INJECTION PRESSURE MULTIPLIER*

Assures solid dense castings by instantaneously multiplying the metal injection pressure during the final travel of the plunger's stroke—where it counts. **Ending pressure increases twice to five times the starting pressure.** If 10,000 lbs. psi. normal pressure is used at the start of the injection stroke, as much as 50,000 lbs. psi. can be exerted during final travel of the plunger's stroke—**packing the metal into castings of maximum density and strength.**

The complete **pressure multiplier** is built right into the hydraulic injection cylinder—is self contained requiring **no** additional space, **no** additional mechanism, **no** complicated adjustments or maintenance, being fully automatic in its operation. Either bullet speed or slow metal injection can be used, as desired. However, in either case the ending pressure is multiplied over the starting pressure —the real requirement for production of solid die castings.

KUX, *producers of the largest line of die casting equipment, has a machine to meet your need! Write for full detailed information and complete catalog.*

*Available on all Kux Hydraulic Die Casting Machines

KUX MACHINE COMPANY • 3934 W. Harrison St. • Chicago 24, Ill.

another use for N-A-X HIGH-TENSILE STEEL



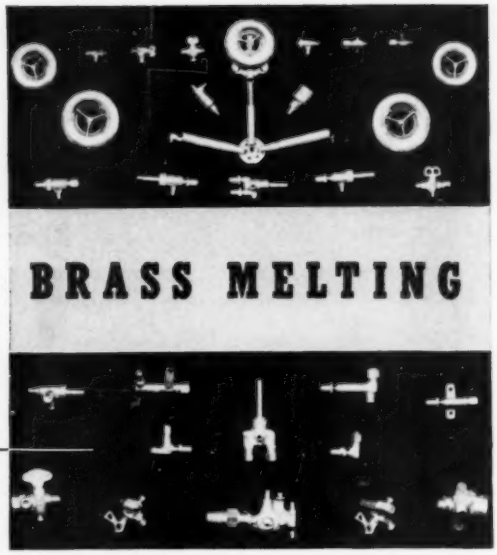
The modern Gar Wood Load & Packer for garbage and rubbish.

MAKE A TON OF SHEET STEEL GO FARTHER. Specify— N-A-X HIGH-TENSILE STEEL

The high corrosion-resistance and durability of N-A-X HIGH-TENSILE makes it ideal for use in garbage disposal trucks and similar applications. Another reason why industry is rapidly changing to N-A-X HIGH-TENSILE.

GREAT LAKES STEEL
Corporation
N-A-X Alloy Division • Detroit 18, Michigan
UNIT OF NATIONAL STEEL CORPORATION

Conversion of Crucible Furnaces at LINCOLN BRASS WORKS, INC. Demonstrates Efficiency and Economy of GAS



CONVERSION of brass-melting crucibles for Gas-firing resulted in three-way operating economy at Lincoln Brass Works, Inc., Detroit. By effective utilization of the fuel the company accomplished

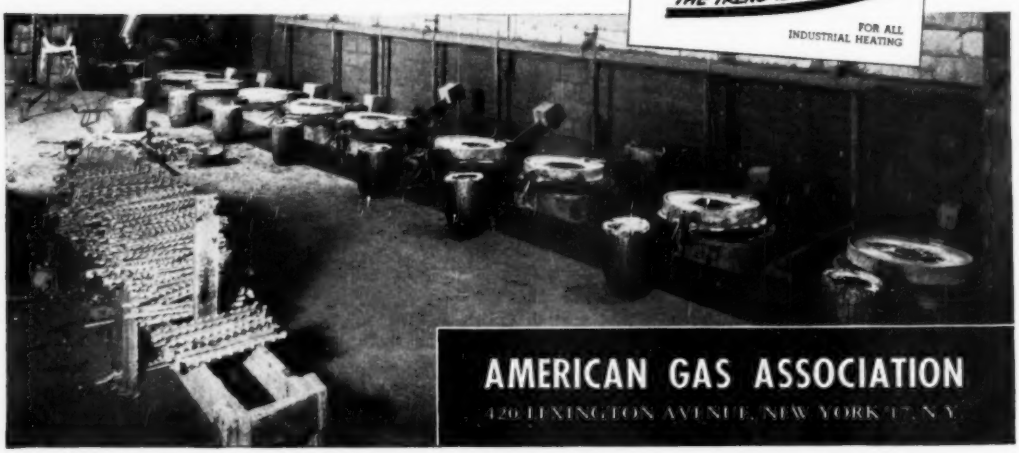
- **33% decrease in melting time**
- **20% reduction in fuel costs**
- **Definite savings in maintenance expense**

An important producer of brass valves and fittings for automotive, marine, industrial, Gas appliance, and farm equipment fields, Lincoln Brass Works is constantly modernizing its manufacturing methods. The conversion of its eighteen crucibles to GAS was a major improvement which Secretary-Treasurer John H. Mueller describes,

"**In addition to the increased melting capacity and lowered fuel costs, we have been getting cleaner metal with Gas-firing. We are now able to keep up production without using all 18 furnaces so we always have some stand-by capacity. You must remember, too, that workmen like GAS because it makes the foundry cleaner and healthier.**"

In brass melting, as in virtually every production-line heating operation, the productive flames of GAS perform the heat-processing tasks rapidly and economically under completely automatic control. Be sure to consult your local Gas Company for recommendations on the effective utilization of GAS.

Section of the brass-melting department showing nine of Gas-fired pit-type crucible furnaces.



Record-breaking NICHROME* V Belt serves 7,000 hours at 2050°F. in Copper Brazing Furnace!



Delivery end of electric copper brazing furnace operated by National Stamping Company—brazed steel parts being delivered by continuous-mesh Nichrome V Belt.

BELT SPECIFICATIONS
length: 98' 6"
width: 20"
mesh : 3/8"
wire : 12 gauge Nichrome V

. . . actual life of this belt extended for many thousand hours more (a large percentage of the time at steel annealing temperature of 1840°F.), but its long service at 2050°F. makes its performance outstanding . . . in fact, puts this belt "at the head of the class."

For though wire belts may last, according to an internationally recognized furnace manufacturer, "practically forever" at lower temperatures such as 1300°—1400°F.—often employed for considerable periods in furnaces of this type—their useful lives are measured by service rendered under heat at 2050°F.

ALL KNOWN RECORDS BROKEN

Says Ashworth Bros., Inc., maker of the belt: "This Nichrome V wire belt was installed in a modern electric copper brazing furnace and operated at the Detroit plant of National Stamping Company from June 1, 1947 to September 24, 1948. Its history, including approximately 7,000 hours at 2050°F. under full load, indicates ***it broke all records for this type of service.***"

MORE OUTSTANDING FACTS

Further information only emphasizes the noteworthy performance of this veteran piece of furnace equipment. For example:

(a) Belt Size—belts of this size, 98' 6" long x 20" wide, must be exceptionally stable to give such long and efficient service.

(b) Production—approximately 380 lbs. of work were handled per hour.

YOUR HEAT-TREATING PROBLEMS AND DRIVER-HARRIS

In selecting *your* heat-treating equipment, remember the outstanding ability of Nichrome V to give top-level performance at high temperatures, such as that of copper brazing. And remember, too, that Driver-Harris has been engaged in finding the correct answers to furnace problems for more than 35 years. Our accumulated experience and unique specialized knowledge will help you to lower operating costs, reduce maintenance, minimize repairs, increase production.



Feed end of furnace—parts being placed on Nichrome V belt
(This belt supplied by Ashworth Bros., Inc., Worcester, Mass.)

50TH YEAR
SPECIAL PURPOSE ALLOYS SINCE 1899
D/H
TRADE MARK REG. U.S. PAT. OFF.
1899 - 1949

Nichrome is manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco, Seattle

*T. M. Reg. U. S. Pat. Off.

TOP-QUALITY ELECTRODES ARE EASY TO RECOGNIZE . . .



The ICE trademark stamped in the socket identifies top-quality electrodes immediately and signifies the most progressive methods known in the art of producing graphite electrodes. For at International, all phases of the manufacturing cycle are carefully controlled to assure the most desirable characteristics . . . electrodes and nipples are checked chemically and mechanically for top-quality and uniformity . . . threads are "miked" to eliminate misfits. There are no better graphite electrodes than International . . . none better for performance . . . none better for economy, that's why so many melters use them consistently.

Graphite products for electrothermic and electrolytic applications

ICE *International* GRAPHITE AND ELECTRODE CORP.

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from this Completely Integrated Plant

WISCONSIN STEEL can supply

BASIC OPEN HEARTH STEEL

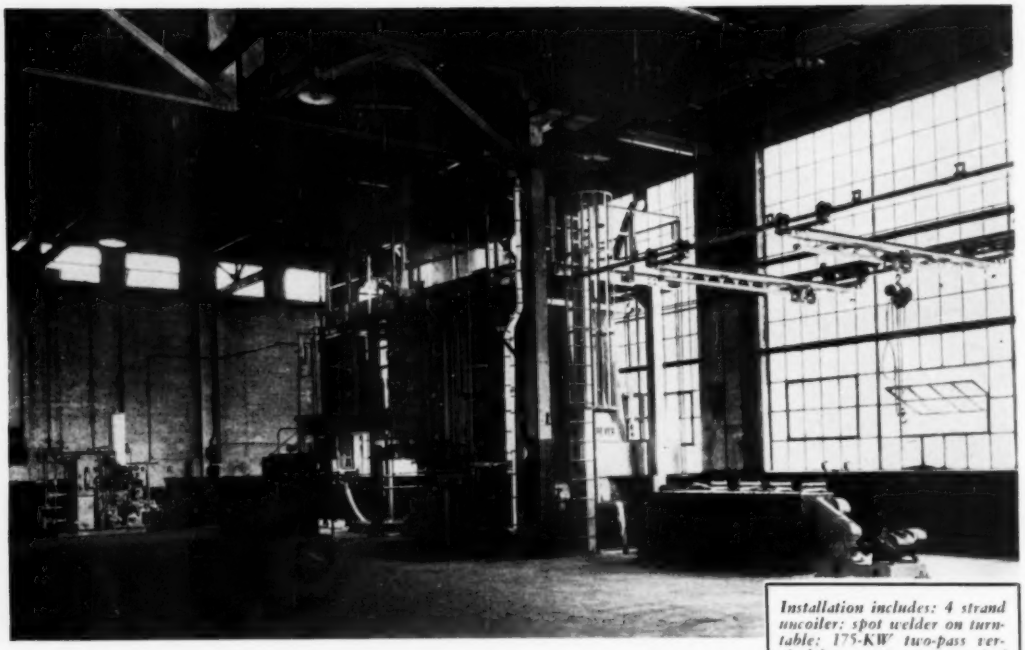
- **ALLOY STEEL**
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  - Tire Sections
  - Spring Steel
  - Special Sections
- **STRIPS**
  - Hot Rolled
- **STRUCTURAL SHAPES**
  - Angles
  - Channels
  - Special Sections
- **PLATES**
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Contact our sales department and let us know your requirements. We are ready to give you the technical and metallurgical assistance you need to solve your problems. Remember, Wisconsin Steel means *quality*.

WISCONSIN STEEL COMPANY, Affiliate of
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180 North Michigan Avenue, Chicago 1, Illinois

WISCONSIN STEEL



Installation includes: 4 strand uncoiler; spot welder on turntable; 175-KW two-pass vertical furnace; two-pass vertical cooling tower; multi-chamber pickling tank; drying unit; master pinch roll; 4-head recoiler; complete bi-nitrogen atmosphere equipment.

DREVER CONTINUOUS VERTICAL STRIP ANNEALING LINE

WATERBURY ROLLING MILLS, INC., WATERBURY, CONN.

Clean, bright or matte finish brass or nickel-silver strip is being annealed continuously in this installation which handles an average production of 2000 #/hour of two 12" strands or four 6" strands .030" thick. Max. strand width 13"; min. width 2"; max. thickness .060"; min. thickness .008".

Non-explosive reducing atmosphere contains low percentages of CO and H— with practically no traces of CO_2 and moisture.

The multi-chamber pickling tank in the line produces die-saving matte finish, or may be by-passed when bright finish is required.

We will be pleased to furnish data obtained from this and other continuous strip lines for comparison with your present annealing practice.

DREVER CO.

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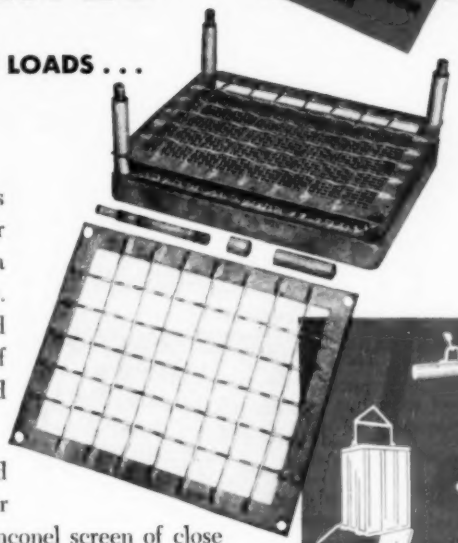
CONTINUOUS FURNACE LINES, HEAT TREATING FURNACES, DESCALING & ATMOSPHERE EQUIPMENT

NEW YORK & NEW ENGLAND—GERALD B. DUFF, 68 CLINTON AVE., NEWARK 5, N. J.
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ROLOCK

FABRICATED HEAT AND CORROSION RESISTANT ALLOYS

FOR HIGHER PAY LOADS . . .
BETTER QUALITY



Rolock has built this rugged assembly for carburizing shafts in a pusher type furnace. Alloy cast grid is used as a base and a train of assemblies is pushed thru the furnace.

Four posts are inserted in the cored corner holes, then bottom Inconel screen of close mesh is placed over grid to prevent shafts dropping thru. Two upper Inconel screens may be positioned by spacers, as desired, with mesh size to suit the work.

Thus, minimum contact area assures uniform quality of carburizing; light weight of fabricated Inconel frames and mesh means high pay loads.

FOR THE CARBURIZING PROCESS

Send for Catalog showing cost-cutting fabricated heat treating equipment.



Offices in: PHILADELPHIA • CLEVELAND • DETROIT
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JOB-ENGINEERED for better work
Easier Operation, Lower Cost

BRL49

ARCOS QUALITY CONTROLS

yield dividends in stainless welds

Every Arcos electrode is the product of careful testing and retesting during development, followed by the close adherence to specification for raw materials, and very strict application of quality controls in manufacturing.

THAT IS WHY Arcos electrodes, in the hands of a competent welder, give consistently sound, trouble-free welds.

THAT IS WHY Arcos electrodes deposit weld metal physically, chemically and metallurgically right for the job at hand.

THAT IS WHY every day of welding with Arcos electrodes *yields maximum production.* Costly non-productive time, chipping and rewelding or repairing weld failures is eliminated.

These are the reasons why the pound price of Arcos electrodes is not a true measure of the value of the welds developed from them.

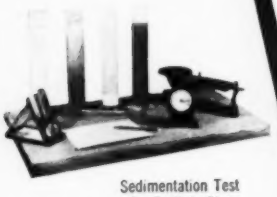
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Use Arcos quality controlled stainless electrodes to keep your weld costs low

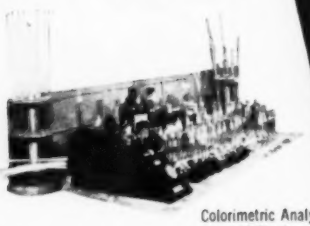
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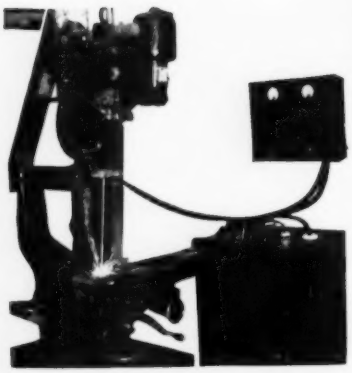
Viscosity Test



Sedimentation Test for Particle Size



Colorimetric Analysis of Steels



Automatic Welding Machine



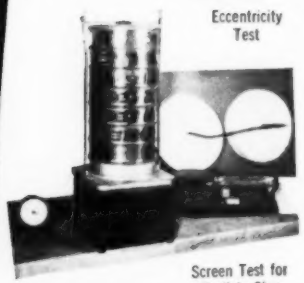
Bulk Test for Coating Materials



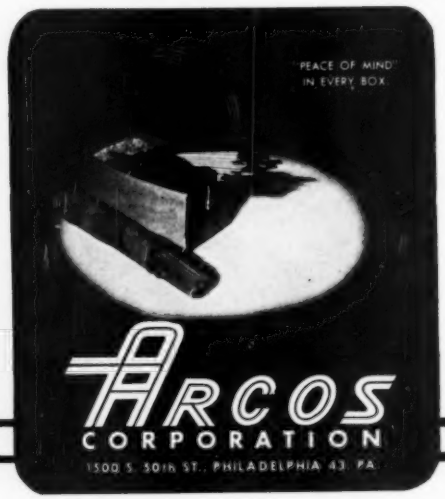
Ferro-Alloy Gassing Test



Eccentricity Test



Screen Test for Particle Size



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If you're redesigning to cut costs, do it around this hole

BY making your hollow cylindrical parts out of Timken® seamless tubing instead of bar stock you save material costs and simplify manufacturing. With Timken tubing, drilling is eliminated because the hole is already there. There's less stock to machine, less scrap. Finish boring is often your first production step. Parts cost less to make.

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To make the most of Timken tubing, use our Tube Engineering Service. We take full responsibility for giving you the most economical tube size for your job—guaranteed to clean up. You're sure of minimum machining time—maximum saving of metal. And you run no risk of not having enough wall thickness to fill out your finish dimensions. To have our Tube Engineering Service make an obligation-free analysis of your requirements, write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

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TUKON for Micro-Indentation Hardness Testing

TUKON TESTER *for* **MICROHARDNESS TESTING**

Used for research, educational and industrial testing of metallic and non-metallic materials—fine wire, minute precision parts, thin metal, superficially hardened surfaces, jewels, plastics, glass, individual crystals or particles of microscopic size. Every day, TUKON Testers are solving problems never before attempted.

All model TUKON Testers may be used with either Knoop or 136° Diamond Pyramid Indenter.

Model MO—Made in both bench and floor type, this is the simplest and most economical model TUKON. It is mechanically operated and applies loads from 1 to 1000 grams. Model MO TUKON is recommended for those interested in light load testing where there is not sufficient work to justify fully automatic control.

Model FB—This model is fully automatic—application of load, period of application and removal of load all being accomplished by electrically operated mechanical controls. Loads from 10 to 3600 grams may be applied.

Probably more microhardness tests have been made on this model TUKON than on any other microhardness tester in the world.

Model LR—This is the ultimate in a hardness testing machine. It is called the "long range" model, applying loads from 10 to 50,000 grams. Model LR contains all the improvements and refinements that Wilson has developed for testing with a pyramid indenter.

SEND FOR Bulletin DH-114 which contains detailed information about TUKON Hardness Testers. We will also include a copy of our booklet DH-7, which gives the experience of several users of TUKON Testers in different fields.



WILSON MECHANICAL INSTRUMENT CO., INC.

ACCO

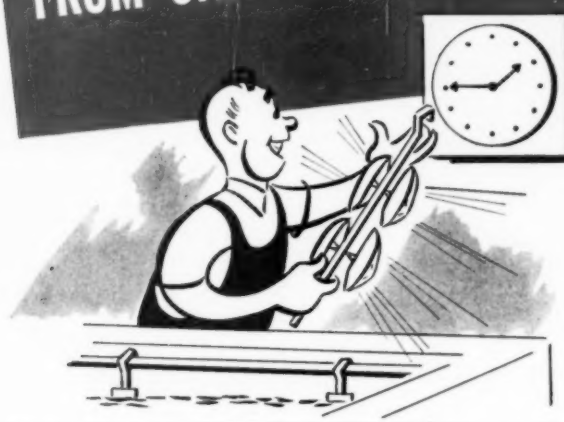
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SMOOTH PLATE

FROM UNICHROME COPPER



...cutting down your need for buffing without having to cut plating speed!

A cross section of a Unichrome Copper deposit will show you *one* reason for its smoothness—you'll see a structure that's dense, finely grained. Another reason is the ability of the bath to operate at high current densities—plating quickly without burning edges. Good corrosion of anodes is a third. When they corrode evenly, as they do in pyrophosphate Unichrome Copper, you get no breaking off of copper fragments, no sludging, both of which are apt to form nodules on the work.

Smooth plating, however, is just one of several outstanding advantages you gain. Which is why we say: "Compare it with any other process, and we believe you'll specify Unichrome Copper every time." Write for our informative bulletin.



FEWER ANODES required, because the bath keeps them free of oxides even at high current densities. Why tie up extra money when Unichrome Copper has 100% anode efficiency—with 50% to 75% fewer anodes?



NO CYANIDE is used in the Unichrome Copper bath—so you not only reduce your stocks of this hazardous chemical, but get a safer bath as well.



CLEAN DEPOSITS never need activation. With no brighteners, no wetting agents used, Unichrome deposits come out clean, ready for the nickel cycle without special treatment.



HELPFUL SERVICE—Unichrome Copper is simple to maintain, seldom gives trouble. But should the need arise, you can always count on prompt help from our engineers and analytical laboratories.

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FOR SURFACES THAT SURVIVE

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Gray Iron Characteristics Include:

Castability
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Low Notch Sensitivity
Wear Resistance
Heat Resistance
Corrosion Resistance
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DURABILITY
Wide Strength Range

Durability...

is synonymous with Gray Iron

"A picture is worth a thousand words." Look at this picture of Hiroshima. See the radiators? They're *Gray Iron.* That's part of what we mean by Durability, defined by Webster as: . . . "enduring".

Throughout the year, we have discussed and illustrated the resistance of Gray Iron to wear, heat and corrosion. These characteristics all contribute to Durability, but they're not the whole story.

Gray Irons are available in a wide range of analyses. They provide combinations of valuable properties unmatched by any other material . . . plus ultimate economy.

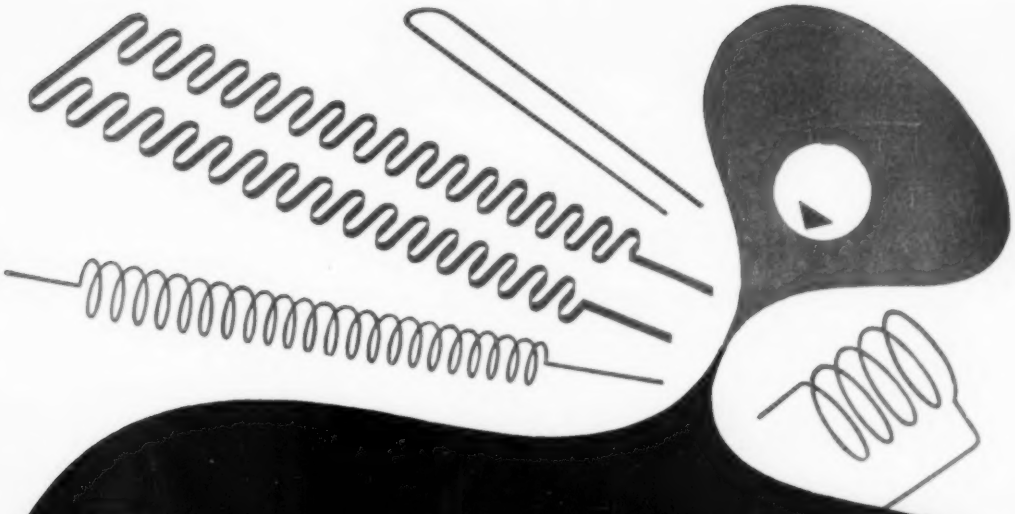
Write for free booklet, "GRAY IRON—Its Mechanical and Engineering Characteristics and Details for Designing Cast Components".

Make It Better With Gray Iron

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GRAY IRON FOUNDERS' SOCIETY, INC.

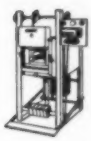
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TYPE OR-104
POT FURNACE



TYPE FR POT FURNACE

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4445 LAWTON AVE. • DETROIT 8, MICHIGAN

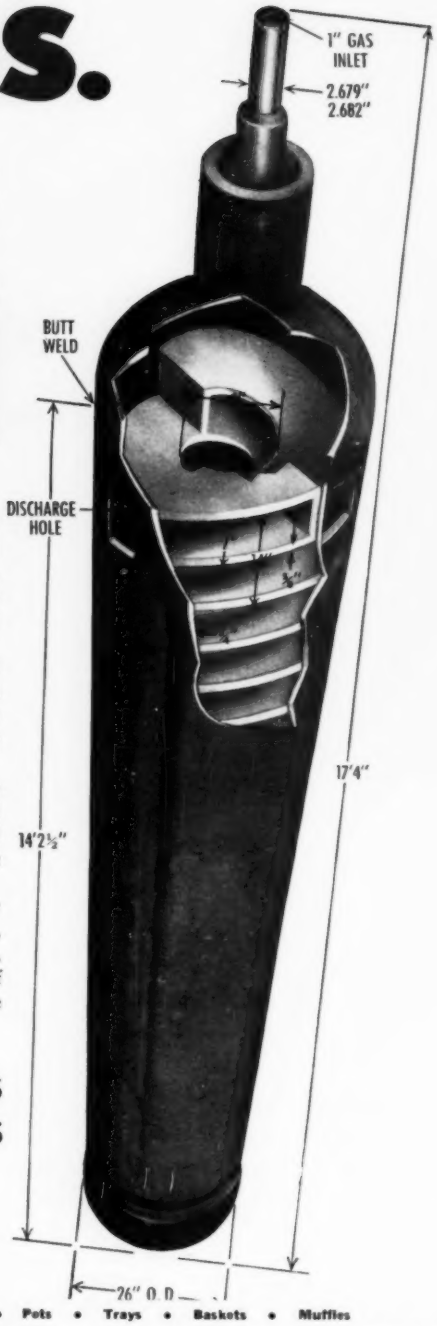
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DOUBLE-PITCH SPIRAL RETORT

CAST IN *Thermalloy*



It had to be right. This carburizing retort will be used for the production of very small parts. Each must pass through the spiral cycle and be discharged at precisely the right time. The double-pitch passage has to be obstruction free. No part can "hang up" and carburize too deeply. Individual inspection of parts is impractical.

Four of these precision-built retorts have been produced by Electro-Alloys in Thermalloy. Interior walls of the spiral passages are clean and smooth. There are no projections or rough spots to block the smooth, steady flow of parts as they pass through their heat cycle.

It is the inside story of these retorts that is important. Two things made them possible. First, research, experience and skill in core making; second, a unique method developed by Electro-Alloys for cleaning the castings internally that doubly insures obstruction-free passages.

These retorts are typical of the work now being done by Electro-Alloys and illustrates how Thermalloy can, and is, being used, for intricate castings regardless of size or shape. It will pay you to investigate the cost-cutting advantages of Thermalloy retorts. A letter or phone call will bring one of our engineers to discuss your problems.

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TRAYS • POTS • CARB. BOXES
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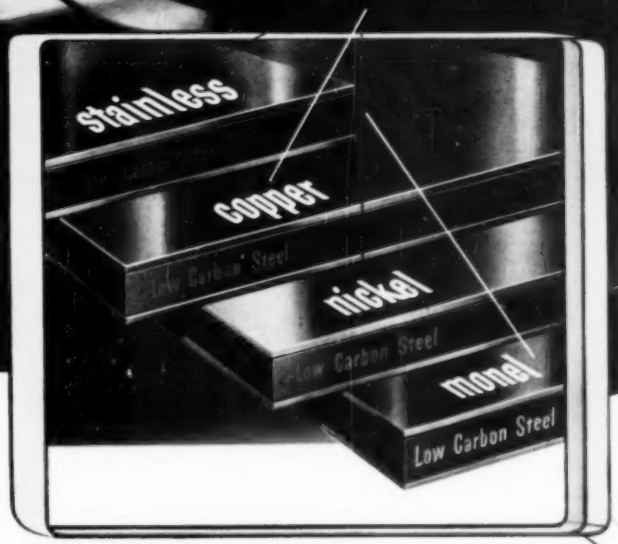
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ELYRIA, OHIO

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Superior Steel
CORPORATION
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HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

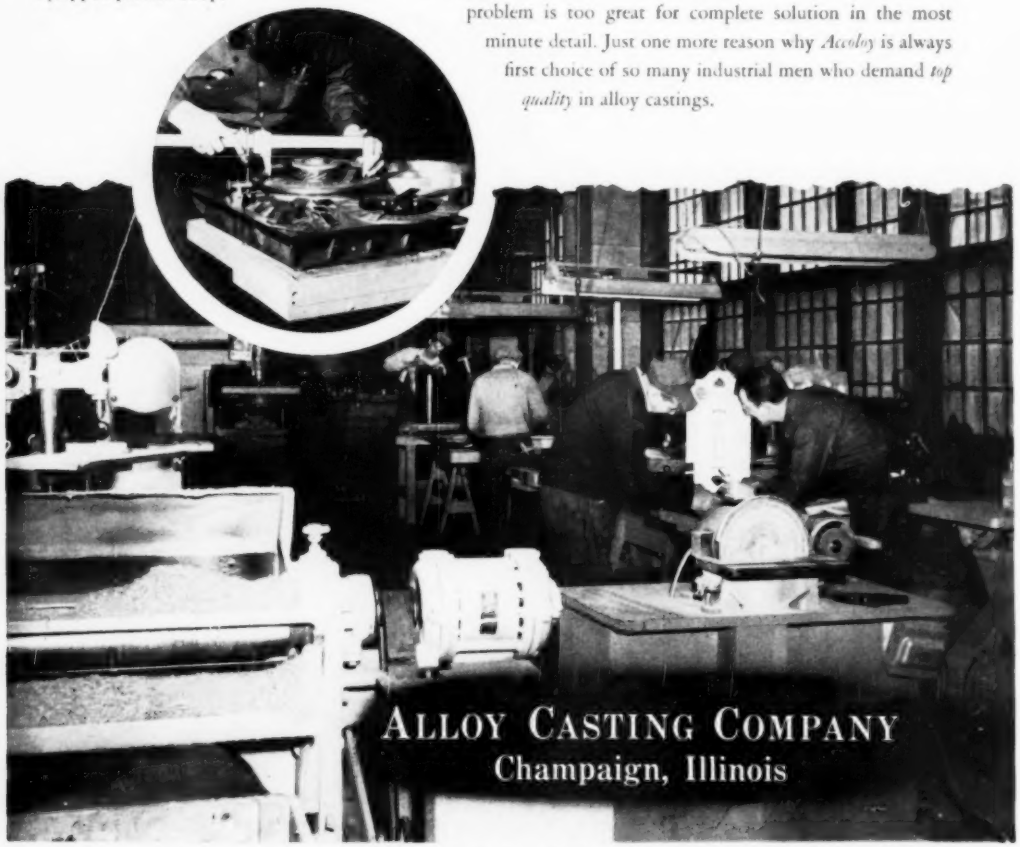
famous for Top quality

...thanks to

THE MOST MODERN PATTERN SHOP
of its size... anywhere!

While maintaining the top quality for which *Accoloy* Castings are famous . . . while striving to give customers better, more complete service . . . we have developed in our own plant the most modern pattern shop of its size—anywhere! Here the finest tools obtainable, operated by long-experienced engineering craftsmen, are used to best possible advantage in making both wood and many metal patterns for alloy castings. No pattern is too intricate, no problem is too great for complete solution in the most minute detail. Just one more reason why *Accoloy* is always first choice of so many industrial men who demand *top quality* in alloy castings.

An engineering craftsman checks a complicated metal turbine wheel pattern in the Alloy Casting Company's modern, completely equipped pattern shop.



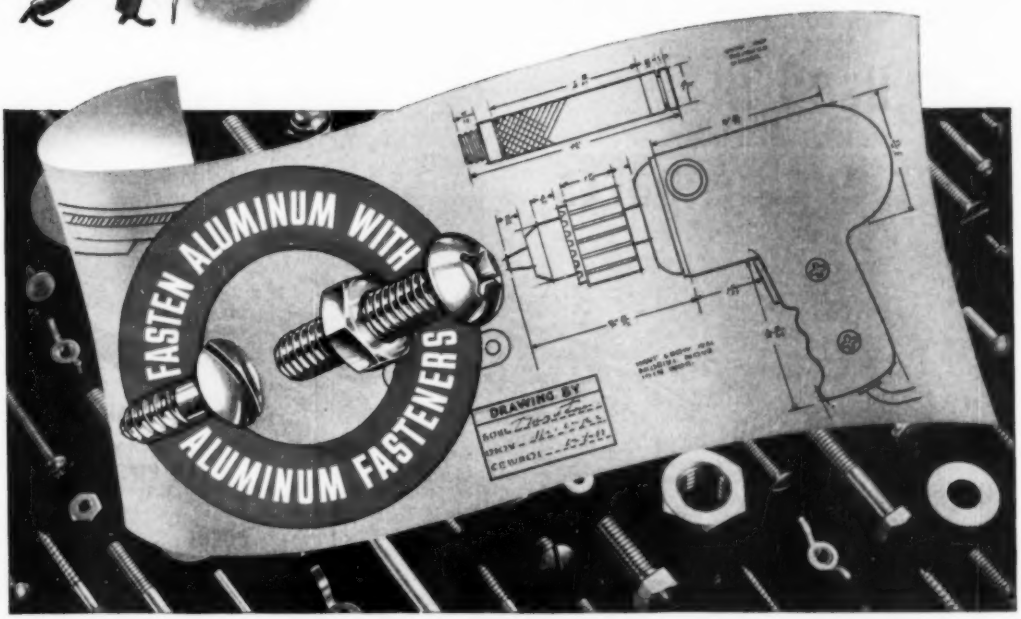
ALLOY CASTING COMPANY
Champaign, Illinois

ENGINEERING OFFICES IN PRINCIPAL CITIES

Chicago: F. J. Staral • Tel: Delaware 7-4430
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SPECIFY ALCOA ALUMINUM FASTENERS

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WRITE FOR FREE SAMPLES

of the types that interest you. And phone your nearest Alcoa sales office or Alcoa distributor for prompt service. ALUMINUM COMPANY OF AMERICA, 2101G Gulf Building, Pittsburgh 19, Pa.

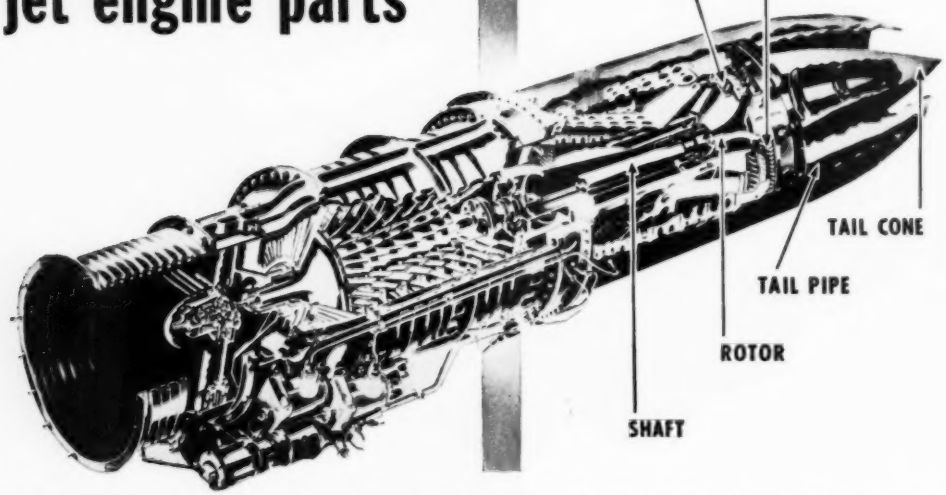
There's no need to run the risk of the galvanic corrosion that can come when aluminum is fastened with dissimilar metals. The complete line of Alcoa Aluminum Fasteners includes all the types required to meet any production assembly need.

Complete ranges of sizes and head types. Slotted or Phillips head. Made to Alcoa quality standards, yet not expensive.

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why TUNGSTEN is used in jet engine parts



Small amounts of tungsten are used in the alloys for turbo-jet parts because tungsten increases their hardness and strength even at very high temperatures. The percentage of tungsten in high-temperature parts depends upon the physical properties desired and the service temperatures to be met. Tungsten-bearing alloys are produced in both cast and wrought forms.

For the manufacture of high-temperature alloys, ELECTROMET supplies a high-quality ferro tungsten conforming to A.S.T.M. Specification A144-39. This ferro-alloy contains 70 to 80 per cent tungsten and a maximum of 0.60 per cent carbon. It is available for immediate delivery in a crushed size of ¼ inch by down and is suitable for all electric furnace additions of tungsten in producing special heat-resistant alloys. Write for additional information on tungsten and other ELECTROMET alloys.

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"With GULF Soluble Cutting Oil

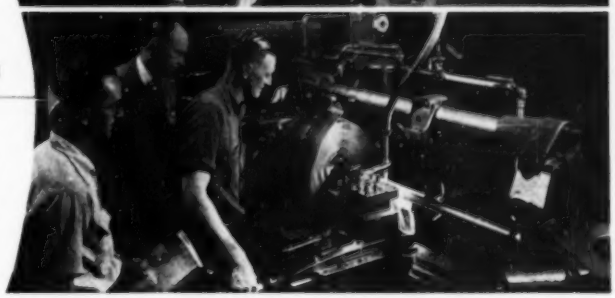
we eliminated warping of cast iron parts



get longer wheel life —no loading



greater production" ...says this foreman



Machine Shop Foreman of a New England manufacturing plant consults with a Gulf Lubrication Engineer on results obtained with Gulf Soluble Cutting Oil on turret lathe work. (Above) This quality cutting oil is also used in this plant in surface and cylindrical grinders.

"We've improved our over-all production picture every month since we adopted Gulf Soluble Cutting Oil," says this Machine Shop Foreman. "For example: Gulf Soluble Cutting Oil eliminated warping of cast iron parts on our surface grinders —wheels cut cleaner and cooler, show less wear. On cylindrical grinders we've improved wheel life and eliminated wheel loading. On turret lathe work we have stepped up production, increased tool life."

Gulf Soluble Cutting Oil meets today's demands for a cooling and lubricating fluid which will do a better job over a wide range of turning, milling, grinding, and many other machining operations.

For further information on Gulf Soluble Cutting Oil—and for one of Gulf's practical slide-rule-type calculators, which will help you maintain desired soluble oil concentrations—send the coupon below.

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Here's REAL Quality Control!

DO YOU HAVE this HANDBOOK?

We are referring to the 176-page book labeled "The Tool Steels of Allegheny Ludlum." It covers LXX, DBL-2, Super Panther, Deward, Saratoga, Huron, Ontario, Sagamore, Potomac, Pompton, Seminole, Utica, and other famous A-L grades. *Get your copy.*

ADDRESS Dept. MP-77

That block or bar or rod of quality tool steel you received from Allegheny Ludlum . . . had to run the gamut of our vigilance committee right up to shipment time. You probably weren't here to watch the technically planned mill procedure, the laboratory controls, and the inspections—but you can quickly appreciate the value of our dozen or more quality safeguards, once the steel goes into service.

Consider, for example, the supersonic reflectoscope. It's uncanny how that ferrets out any internal flaw.

This daily ritual of checking, testing, and inspecting at the various stages of production means that, in effect, we are operating our own "Bureau of Standards." By thus insuring quality, we protect you—the customer. You get better results.

For sound, clean, tool and die steels —uniformly accurate in analysis, structure, hardness, and size—call A-L.

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Pittsburgh, Pa.

TOOL STEEL DIVISION: DUNKIRK, N. Y.

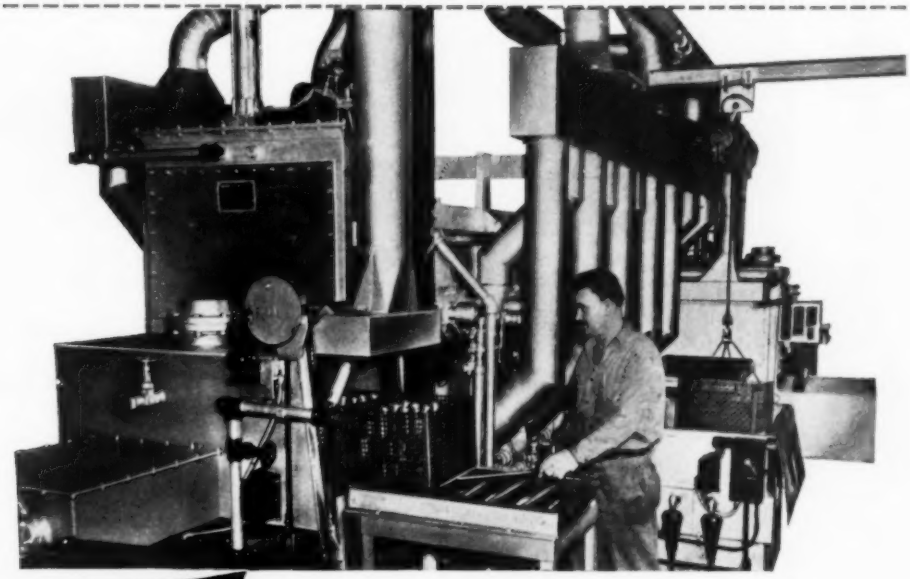
Fine Tool Steels Since 1854

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YOU CAN BE **SURE**.. IF IT'S

Westinghouse



FOR THE MAN WHO CAN'T BE SOLD

Here's the solution to your Gas Carburizing Problems

Westinghouse Therm-a-neering has the answers. This engineering and metallurgical service is offered with no obligation to the man who "can't be sold", but, who is willing to accept *proof* of efficiency and dependability. Therm-a-neering custom-builds equipment to fit your individual requirements, assuring smooth and economical operation of your heat-treating line.

Take the carburizing furnace shown above, for example: one continuous and complete operation puts all parts through the same cycle, same atmosphere, same temperature. Uniformity of parts is assured. Rejects are eliminated.

And the work is done fast. No handling of parts is required between charging and discharging. Doors open automatically. One operator handles all work easily. Production is maintained at 800 net pounds per hour.

This installation is typical of the way Westinghouse furnaces—both gas-fired and electric—are answering today's production problems. And because Westinghouse engineers have no favorite to play, they can study your problems from an unbiased point of view in helping you select the equipment to do your job most efficiently and economically.

Let Therm-a-neering help you. Call your nearby Westinghouse representative for details, or write Westinghouse Electric Corporation, 181 Mercer St., Meadville, Pa. J-10350

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ENGINEERS—Thermal, design and metallurgical engineers to help you study your heat-treating problems with a view toward recommending specific heat-treating furnaces and atmospheres.

RESEARCH—A well-equipped metallurgical laboratory in which to run test samples to demonstrate the finish, hardness and metallurgical results that can be expected on a production basis.

PRODUCTION—A modern plant devoted entirely to industrial heating.

EXPERIENCE—Manufacturers of a wide variety of furnaces—both gas and electric—and protective atmosphere generators.

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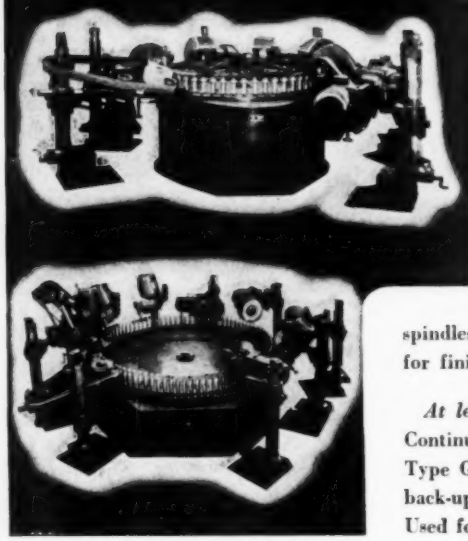
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Furnaces

ROTARY AUTOMATICS • SEMI-AUTOMATICS • STRAIGHT LINE AUTOMATICS

• FOR HIGH PRODUCTION POLISHING AND BUFFING •

ACME CONTINUOUS ROTARY Automatics



Put Polishing and Buffing Operations On A Production Basis!

At left above: ACME 6-ft. Continuous Rotary having 50 continuous revolving chuck spindles—1 polishing head and 5 buffing heads. Used for finishing octagon plumbing goods escutcheons.

At left: ACME 10-ft. Continuous Rotary having 96 Continuous Revolving Spindles. Used with 2 ACME Type G-3 Universal polishing belt heads with floating back-up wheel and 8 ACME Type G-3 buffing lathes. Used for polishing and buffing brass door knobs.

ACME Continuous Rotaries are built in various table sizes from 20 inches to 10 feet or more in diameter. They are adaptable to a great many arrangements that keep finishing costs down on polishing and buffing operations.

ACME builds Straight Line and Rotary Automatics, Semi-Automatic and Special machines to handle virtually any type or size of polishing and buffing operation on a production basis. Acme Automatics cut finishing costs and get more output per man-hour. Payroll dollars buy more production when ACME machines are used!

SPECIAL MACHINERY — AUTOMATIC BUFFING MACHINES

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1645 HOWARD ST. DETROIT 16, MICH.

Builders OF AUTOMATIC POLISHING AND BUFFING MACHINES FOR OVER 30 YEARS

YOU CAN BE **SURE**.. IF IT'S

Westinghouse



with the NEW WESTINGHOUSE X-RAY THICKNESS GAUGE



A look at the remote control panel pictured above shows at a glance the advantages of the Westinghouse X-Ray Gauge over other methods of thickness gauging.

1. Controls may be set to operate tolerance limit indicator lights for high-speed mill applications or to operate the reject gate on a classification line.
2. Gauge can be calibrated from operator's control panel.
3. Comparison standards permanently mounted in lower arm of gauge are set up automatically to thickness chosen on control panel. No manual handling of calibration samples.

Here's how to gauge the steel strip on high-speed, cold reduction mills or the slower classification line. The Westinghouse X-Ray Thickness Gauge provides a direct comparison method of gauging accuracy which is independent of strip speed and yet holds to minute tolerances. There is no contact between gauge and sheet . . . no damage to strip surface . . . no mechanical gauging wheels to maintain.

What's more, operation and calibration of the gauge are handled by remote control at the operator's control panel.

The gauge employs two x-ray tubes and one photo-multiplier tube, resulting in complete circuit stability. It is compact, of rugged mechanical construction and experience-designed to give "steel-mill" type continuity of service.

Here are other advantages:

- Rapid setup time for each run
- Wide throat for easy threading of strip
- Arms in suitable lengths for specific requirements
- Unit may be installed to allow lateral scanning of strip

All in all, the new Westinghouse X-Ray Thickness Gauge is the direct route to economy for you and quality for your customers. Get the facts today. Call your local Westinghouse representative, or write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa. J-08223

Westinghouse

X-RAY

the end of horse and buggy days



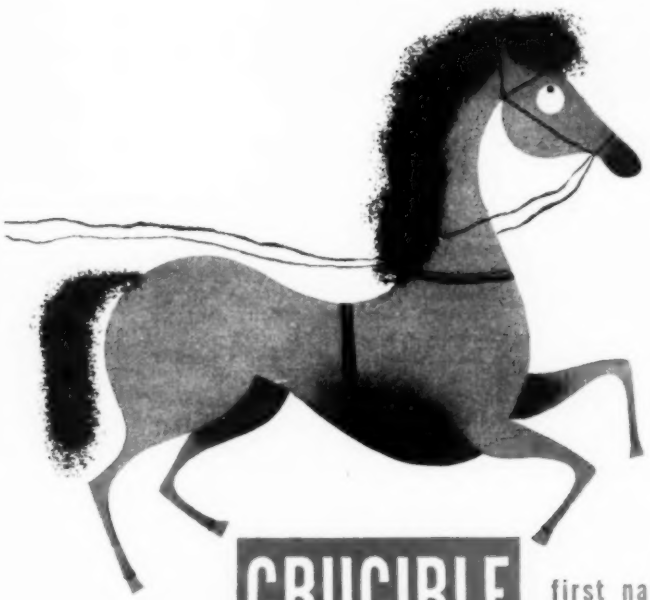
for stainless sheet and strip

Automobiles were once designed as horseless carriages—even to the dashboard socket for a needless whip. Stainless steel production, too, once struggled thru horse and buggy thinking. More power, heavier rolls, more care in surface finish —and stainless sheet and strip came forth a step-child of carbon steel methods. Today's modern strip mills have changed this, giving stainless production new concepts of quality.

CRUCIBLE, one of the pioneers in stainless steel, has gone still further. Now, *for the first time*, hot and cold rolled stainless steel is made a *specialty product*, by specialty production methods, in a mill built specifically for this purpose—in widths from ½" to 50" inclusive, and in all gauges, grades and finishes.

This is more than merely another source of supply. For, with this new mill at the Midland Works and the Trent Tube Co. joining the organization, CRUCIBLE can now supply you with *every* form of stainless. And, in sheets, plates, strip, bars, tubing, forgings, wire and castings, you can rightly expect the best that modern facilities and generations of *specialty product* leadership can provide.

CRUCIBLE STEEL COMPANY OF AMERICA, 405 Lexington Ave., N. Y. 17, N. Y.
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CRUCIBLE first name in special purpose steels

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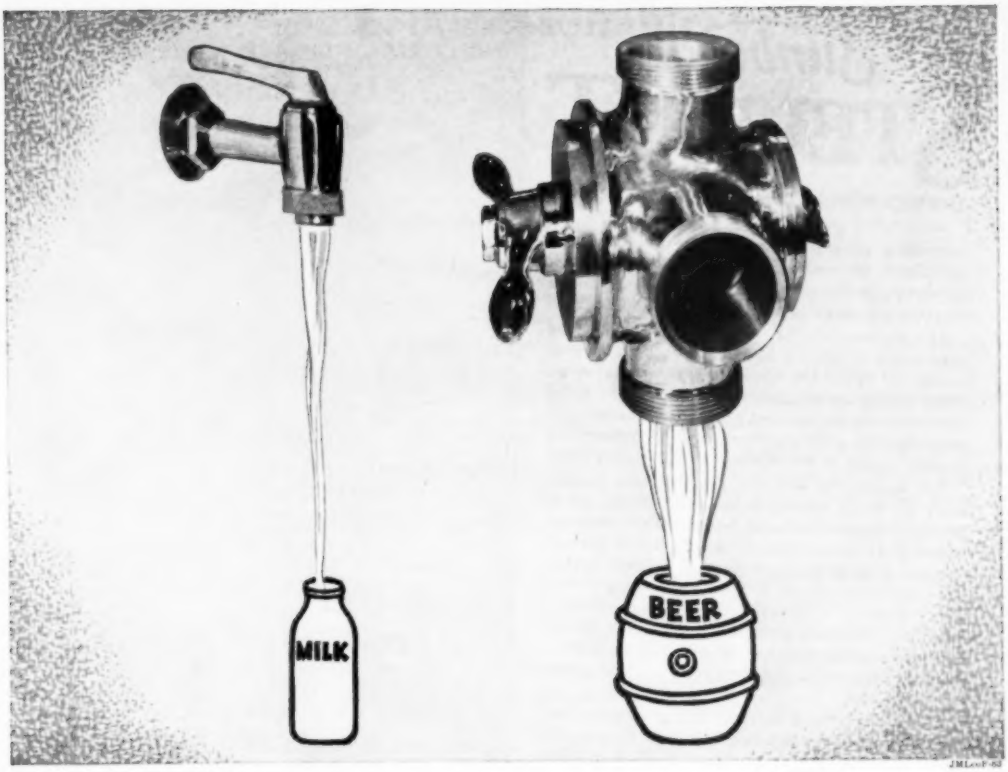
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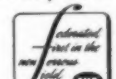
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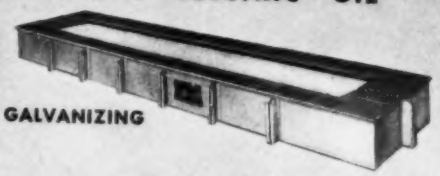
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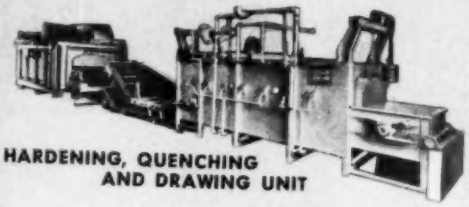
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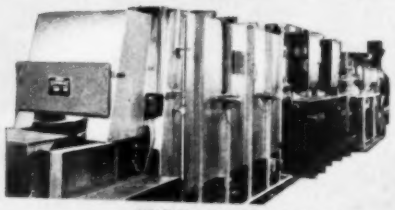
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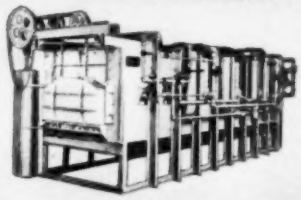
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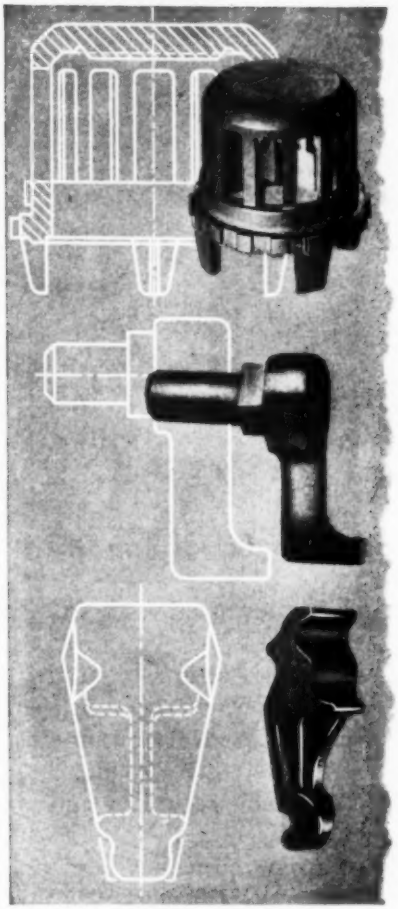
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Metal Progress

Ernest E. Thum, Editor
Taylor Lyman, Associate Editor

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Critical Points

By The Editor

Metallographic Exhibit

IT IS NOT too early to start thinking about the Metallographic Exhibit at the next ASM convention. Get the boys together and select the best work of the current year. At the exhibit, in Cleveland, you can see how it stacks up alongside the best from metallographers throughout the country. As in previous exhibits, there will be no annoying red tape. Complete announcement will be made in *Metals Review* for July.

Some New Ideas About Foundry Work

RIDING from Chicago to Champaign, in central Illinois, began to doubt the oft-repeated statement that the oldest of man's arts are least hospitable to modern improvements, for here was Agriculture, represented by endless cornfields geometrically sprouting in rows and ranks, and dozens of tractors busily cultivating, yet not a single team of draft horses to be seen. And once in Champaign, at the Alloy Engineering and Casting Co.'s plant, found the most ancient Foundry Art being taken apart and each of its fundamentals so modified that, on reassembly, the operations would hardly be recognized by Biringuccio or Agricola. The problem being studied under Navy research and development contracts (in which the Bureau of Ships and Bureau of Aeronautics are participating) is how to make a well-designed casting — "well-designed", mark you — in such a way that it will need no machining, retain maximum fatigue resistance, and will be accurate to shape even after numerous runs at highest temperature. Castings made in conventional sand molds and cores are rough on the surfaces; entrapped within their body are many fragments of sand, and bubbles of gas from moisture and binders; thus they have a multitude of stress raisers both outside and inside. Lack of control of casting temperature, pouring rate, and cooling velocities mean wide variations in grain size, yet large grain size usually means low endurance to alternating mechanical and thermal stresses. The requirements could be met, then, as reasoned by H. H. Harris, who has general direction of the research project, by a clean casting of nickel-chromium-molybdenum alloy, highly accurate in dimension, with uniformly fine crystals and very smooth surfaces.

Yes, but how? Surface roughness, dirt inclusions and blowholes can probably all be corrected by throwing molding sand out the window, using instead powdered refractory materials. Mold surfaces then can be almost as smooth as glazed chinaware. The minimum amount of moisture necessary for binder is baked out by di-electric (radio frequency) heating — such molds and cores are really dry, even slightly fritted. The aim of associated ceramic investigations is to be able to formulate mixes of minerals, carbon, metal powders, exothermic chemicals, or plastic threads so the mold will have proper resistance to the molten metal, proper heat capacity, and minimum necessary strength at first, but become friable enough to be cleaned out of cores. (This portion of the work has already been so successful that new ceramic materials are used in many portions of the sand molds in present production at allied foundries in Champaign and Boston. Likewise the Bureau of Ships has used these newly developed mold materials for casting test bars. The assembled unit, capable of bottom-pouring six rectangular bars of graded thickness, is stored in airtight cans until used; molding variables, which have such a large influence on strength of thin sections, are at last eliminated. Likewise the conductivity of the molds is so uniform that the grain size of the casting is an accurate measure of the pouring temperature.)

So much for smooth surfaces. Assuming that no loose dirt or dust is left behind, the next problem is to get metal into the mold without turbulence and scour. Slow pouring of rather cool metal is also desirable for fine grain size in the casting; the ideal condition would simulate the continuous casting of aluminum-alloy slabs,

wherein the mold extracts heat at the same rate it enters via liquid metal. Centrifugal casting of disks or hoop-like shrouds also seems to be desirable, although in this event special gating is required to prevent slap or scour of metal against mold when they are moving at different speeds and directions.

Pouring at a controlled rate and at proper temperature is by no means easy. Even the accurate and continuous measurement of temperature within the ladle awaited improvements in pyrometer protection tubes. A bottom pour, or teeming, ladle seemed to be far better than the conventional "tea pot"; the stream from the former would be much closer to the temperature measured within the ladle. But here an unexpected trouble stymied progress: Nozzles of sufficiently small diameter would freeze — or scour if you ran them fast enough to prevent freezing! All right, make them of graphite and build in a small electric coil for auxiliary heat. Also bathe the exit stream with argon to avoid oxidation on the short trip from ladle to downgate. Then mount the ladle and observational equipment on a scale platform, swing this above the spinning mold, keep centered on the axial down-gate with an electric eye, and record continuously weights and temperatures. Then you will know what you are doing!

Possibly this summary has gone far enough without noting that the turntable which spins the mold also carries a bank of capacitors and electrical connections so that extra heat can be put into any part of the casting either to slow down the crystallization rate or to keep a channel or a reservoir liquid. Likewise refrigerated brine can be led in to copper cooling coils for its opposite effect. Furthermore, the whole thing can be tightly covered and the casting done under controlled or inert atmosphere — either pressurized or under partial vacuum.

Sapient Observation

R. O. EASTMAN, who conducts research for periodical publishers, writes, "You can't do anything about anything that you don't know anything about."

Difficult Stampings of Strong Steel

RUNNING down a rumor that the automotive body designers are again making all-but-impossible demands for deep-drawn shapes for the 1950 models, revisited Great Lakes Steel Corp. near Detroit where 10 years ago CHARLES LAUFLE and CLARENCE ALTENBURGER started to promote the idea that high yield strength (even in low-alloy sheet) was frequently more necessary than high elongation when making certain types of difficult stampings, and was pleased to find that their efforts have been so successful that they are now making about half the American tonnage currently classed as "weldable, low-alloy, high-strength steel". The EDITOR had to confess that he thought of this class of material as "structural", and hence visualized angles, plates and forging billets, unmindful that sheet metal parts and assemblies can also act as load-carrying members. With pardonable pride, LAUFLE pointed to an advertisement prepared in 1944 which showed a car of 1949 shape with front and rear bumper (of his favorite steel, of course) extending so far back and front that they met and formed a continuous crash guard around the whole body. Such a progressive viewpoint, together with technical information understandable to die makers and stamping foremen, has just about corralled the business in bumpers. These are polished in the flat, covered with protective lacquer ("liquid envelope"), formed, stripped of the rubbery coating, and plated. The steel has sufficient strength, both naturally and induced by cold work, for everything but a crash; obviously it is more economical to use than a simple carbon steel that would require strengthening by heat treatment (with subsequent straightening, descaling and polishing) and even then be so stiff as to transfer collision damage back into the car's underframe. . . . . ALTENBURGER says that, despite extensive scientific studies of cold forming theory, new stampings are still achieved by traditional methods: Make the dies like similar ones which have been successful in the past, and if too many stampings crack, blame the steel. This occurs the more frequently in shops with the least experience, and in this respect the situation is worsened by the turnover in manpower since 1940. He is now working on the idea that any large shop could classify its stampings as to nature and as to difficulty, and range them from easiest to hardest in a "stretchability" series. Then, if the shop has made successfully a shape far down on the series, it should not have much trouble with a new one similar to another placed somewhat higher on the list.

A Correction

AN ERROR is contained in the Editor's summary of the article on "Selection and Heat Treatment of Cutting Tools" by Norman I. Stotz on p. 485 of the April issue. The 5-1-1 chromium-molybdenum-carbon steel developed by Messrs. Stotz and Scott is an air hardening tool and die steel for cold work, not a "hot work steel", as said there, nor a steel for die casting dies.

By Albert W. Merrick
Chief Metallurgist
Austenal Laboratories, Inc.
New York City

Precision Investment Casting

IT IS almost a requirement that all articles on investment casting start off with a reference to Cellini, the incomparable artist. Also with a statement that the pre-war utility was principally confined to the manufacture of dentures. Consider these things said. Furthermore, since the Editor of *Metal Progress* has summarized clearly the recent history in the March issue (p. 325) and the present author in *The Iron Age* for Feb. 10, 1944, this matter can rest, and we can proceed immediately to an exploration of the possibilities, limitations and problems of precision investment casting, so that engineers, designers and metallurgists may be able to cooperate more efficiently to the mutual advantage of both the users and manufacturers of castings.

The principles are simple. A replica of the desired casting is formed of wax; sprues are attached, also of wax, and the whole is "invested" in plaster. This "investment" is then allowed to harden; it is carefully heated, which melts the wax. Into the cavity thus formed, metal is cast.

Gypsum (calcium sulphate), mixed with fine silica, was the setting agent used in these earlier investments. They are good only for metals with melting points below 2000° F. The lack of more refractory investments, if nothing else, prevented the process from being used for such high-melting metals as oxidation and corrosion resistant alloys.

This was the "key log" broken in 1932 by Charles H. Prange of Austenal Laboratories by devising an investment consisting entirely of silica, based on the controlled hydrolysis of ethyl silicate as the setting agent.

Limitations — By this means, castings can be made of any metal or alloy that is castable by ordinary foundry processes. For commercial production, the practical upper limit of casting temperatures would be about 3200° F.

Then, too, there are a few reservations that should be kept in mind. Elemental metals such as oxygen-free copper, or very pure nickel or iron, should not be considered as commercially feasible in the ordinary usage of this term. Furthermore, there are certain alloys that are troublesome when making castings like turbine blades that have very thin edges, since they require high casting temperatures. Some of the stainless steels (especially the straight chromium-iron alloys such as type 410) are likely to give trouble from slaggy surfaces that leave a pitted condition; this can be controlled to some extent but production costs are higher and other alloys should be used when possible for thin-edged sections. While we have had no experience with the austenitic manganese steels, I believe they would present a similar difficulty — even to a greater degree. Alloys with titanium also present difficulties with slag formation, and some with aluminum (Alnico compositions, for example) are still more difficult to handle.

On the other hand, toolsteels cast easily and respond normally to heat treatment. Some precautions must also be observed: There is some decarburization at the cast surface, for which a grinding allowance of about 0.010 in. must be made if full hardness is desired. It should also be kept in mind that shock resistance is lower for castings than for tools machined from rolled or forged stock of the same analysis. In certain instances designs may be changed so that excellent service can be obtained from cast parts that might

otherwise be unsatisfactory. This observation applies to toolsteels cast to shape by *any* foundry process, if the as-cast structure is not modified by subsequent hot work.

Mechanical Properties

Only a few specific points can be offered for consideration in the available space:

First, it should be remembered that we are dealing with castings and that mechanical properties of the metal are nondirectional. We are often prone to compare the properties of castings with those of rolled or forged stock, forgetting the elementary fact that customarily the properties reported for structural steels, for example, are those obtained from test specimens taken in the direction of rolling or forging — the most favorable direction.

When test bars are machined from specimens taken *transverse* to the direction of forging, the ductility, as measured by percentage of elongation and the impact strength, is materially reduced. These facts are, of course, well established, yet there is a tendency on the part of many designers, engineers and writers of specifications to overlook this elementary but fundamental fact.

For example the latest (1948) edition of Bullens' "Steel and Its Heat Treatment" (Vol. I, p. 118) quotes the following properties for heavy plate rolled of high-strength mild-alloy steel, tested as-rolled in the three principal directions:

	Longitudinal	Transverse	Perpendicular
Tensile	65/75,000 psi.	65/75,000 psi.	65/75,000 psi.
Yield	45/50,000 psi.	45/50,000 psi.	45/50,000 psi.
Elongation	30%	20%	2 to 4%
Reduction	65%	55%	5 to 15%

It is certain that investment-cast test bars of such a steel would have considerably better figures for percentage elongation and reduction of area than those in the last column, and would always approach and frequently exceed the values given in the middle column.

There is a second point, especially pertinent to precision investment casting: It is very convenient to cast the customary 0.252-in. diameter test bars "to size" (threaded grips included) so that no machining is required. A further advantage is that the surface of the casting is not machined off the test bar and it influences the results according to its excellencies or deficiencies. The industry very naturally adopted this as common practice. In many types of alloys, the shrinkage characteristics, molten to solid, are such that this method of casting produces sound metal in the gage length section, and satisfactory tensile properties are obtained.

There are, however, some very important exceptions, notably plain carbon steels, low-alloy steels and some of the stainless types. Test bars of such materials, cast as described above — that is, gated at the ends only — will invariably show low elongations compared to those generally accepted as typical for the respective composition by the alloy steel casting industry.

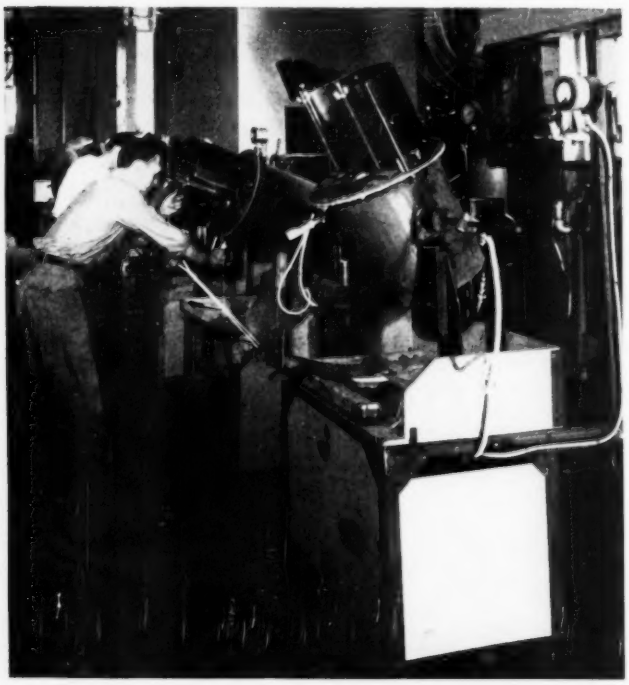


Fig. 1 — Melting and Casting Machines for Making Precision Investment Castings. Small carbon electrodes enter the steel casing through the trunnions and heat the metal, held in an internal crucible, by indirect arc. The nearest operator is measuring the temperature with an optical pyrometer. The mold (investment) is clamped upside down to the furnace lid, the combination then inverted, and the mold filled with the aid of air pressure momentarily injected into the furnace shell

The cause is not inherent in the investment casting process, and the solution quite simple. Cast test bars are no exception to the laws of nature, and must be adequately fed (as any other casting) in order to be sound. A uniform cross section of 0.250 in. diameter and 2 in. long will exhibit a varying degree of shrinkage, dependent upon the type of alloy. This shrinkage is almost of microscopic character, and cannot be detected in radiographs, but it can be seen by sectioning axially and deep etching. By feeding the gage length section adequately, sound bars can be produced with good ductility as shown by the elongation and reduction of area.

To prove this point and to eliminate all other variables besides feeding, a cluster of bars may be cast as shown in Fig. 2. Three of them are fed from ends only, while the remaining three simulate the "keel block" common in steel foundry practice. Test results are shown in Table I, alongside, and are quite typical and representative of dozens of tests made on 1020 and other steels in this group. All bars were annealed at 1650° F. Four were then quenched in water from 1675° F.; corresponding pairs were tempered at 1000° F. and at 500° F. respectively.



Fig. 2 — Cluster of Six Test Bars Cast in One Investment. Three of them are cast to size, gated from ends only; three others simulate the standard keel block of the steel casting industry and are later machined to shape along the gage length. Test results follow:

Table I — Tests on Cast 1020 Steel (Carbon 0.23%)

Property	Keel Block			As Cast		
	Annealed Only	Tempered		Annealed Only	Tempered	
		1000° F.	500° F.		1000° F.	500° F.
Ultimate strength	61,700	87,200	157,000	64,200	90,000	140,000
Yield (0.2% offset)	40,000	66,000	130,000	44,000	77,500	135,000
Elongation in 1 in.	34.2	17.2	9.4	17.2	4.6	3.2
Reduction of area	51.0	57.0	30.5	29.0	19.0	2.0
Hardness	B-75	B-98	C-39	B-75	B-99	C-42

Consistency of Properties

There is also a good degree of consistency between bars from the same cast and casts from a series of heats of a given range of composition, when casting practices are under control — the routine of every good foundry. See Table II, where three bars only were tested from each of a series of six heats. These were keel-block bars, machined to shape. Alloy was "Ascoloy" conforming to A.M.S. specification 5354. Composition was: 0.12% max. carbon, 12 to 14% chromium, 1.8 to 2.2% nickel, 2.5 to 3.5% tungsten. Prior heat treatment consisted of holding at 1300° F. for 1 hr. and then air cooling.

By the "as-cast" practice, test bars of this alloy will show a large spread in figures for elongation, and usually will be less than half those shown in Table II. Specification A.M.S. 5354 calls for a minimum of 5% in 1 in., rather than 10%, because the "as-cast" practice is requested.

(Similar data could be presented for the alloys in this group previously mentioned — plain carbon, low-alloy and hardenable types of stainless steels. On the other hand, some of the high-temperature alloys have freezing characteristics such that the ductility values of as-cast and keel-block test bars are quite similar and consistent.)

The old problem of "test bar properties" versus "casting's properties" will probably never be solved to everyone's complete satisfaction. The writer would like to suggest that investment castings be tested *directly* wherever possible, since at present they are small in size. Castings should be as sound *in critical sections* as we know how to make them. This remark is intended to include test bars. Tensile test bars usually have at least two functions: First, to verify the mechanical properties of a specific heat of alloy, generally referred to as a "master melt" (and not to indicate the amount of shrinkage produced in a length eight times the diameter). Second, to

Investment casting was the process used to cast (accurately to shape) the millions of impulse blades for aircraft engine turbosuperchargers. High temperature alloys, difficult to machine and forge, are also cast into blades for gas turbines. The author, who is connected with the pioneering firm in this industry, discusses the economics of the process and suggests applications whereby complicated shapes of more common steels and alloys may be produced in competition with conventional mass production methods. The metals and alloys that can be cast, cover a wide range, including metals with melting points up to about 3000° F.

indicate the expected properties in castings subsequently made from a "master melt", which have been gated and fed in a manner aimed to produce soundness in critical regions.

In research work, we certainly need to know the best properties that are capable of being developed in an alloy — its "inherent" qualities — and should not be misled by a shrinkage characteristic that is very capricious in its manifestations on test bars cast to size.

No specific manner of gating test bars is being advocated, but rather that test bars be cast with whatever method of gating will yield bars developing the maximum properties with a reasonable degree of consistency.

The writer has elaborated this point with intended emphasis, because all existing Aeronautical Materials Specifications (A.M.S.) covering investment castings now call for test bars "as-cast", which is not objectionable in certain high-temperature analyses. However, specifications are now in preparation for some low-alloy steels, and this point should be given due consideration.

Melting and Casting Methods

Any method for melting metal may be employed in investment casting that is suitable for small unit melts. The same procedures, precautions and experience are required that are necessary to control quality in foundries making large castings. There are also many methods of casting, and often the method of melting will largely determine the casting method.

When making small nonferrous castings in investments, metal is often melted with a gas torch and cast by the centrifuge method in a single-arm machine, or — if melted in crucibles in larger quantities — by a spinning table with several molds at a cast. With certain castings gravity pouring may be employed.

With steels and high melting point alloys, indirect arc and induction furnaces are commonly used. Where very low-carbon alloys must be cast, induction melting may be necessary, whereupon some form of centrifuge machine may be used in casting. Other methods use gravity, directly from the melt or by transfer ladle (if the casting permits and large unit melts are made).

Vacuum is sometimes applied to the investment from the bottom, thus getting the benefit of some atmospheric pressure effect, in addition to the static head of metal.

The indirect arc pressure machine shown in Fig. 1, p. 54, is a very economical and efficient unit. It is used for most of the high-temper-



Fig. 3 — S.A.E. 1020 Parts (to Be Case Hardened) for Textile Machinery; About Half Size

ature alloys, and for melting the stainless and low-alloy steels. The investments are clamped directly over the pouring spout, the furnace inverted, and pressure applied by air (or inert gas) through the melting crucible.

Economic Aspects

In comparison with such methods as screw machine production, or die casting, investment casting employs a much higher proportion of labor. It can seldom compete with machining methods where long runs are involved on suitable steel parts, or with die casting. For small runs, or when designs are still experimental, it can often compete because of its lower tooling-up charges. Where parts are too complicated, or the alloys required are difficult to machine, investment castings very often offer important economies. Because of their accuracy and lesser amount of finishing required, they often compete favorably even with sand castings — especially on small parts.

For parts requiring resistance to high temperatures made of alloys not readily machined or forged, and that have complicated shapes and contours, investment casting is often the *only* practical means of production.

The largest application has been in the field of parts that are highly stressed at elevated temperatures. Many of the alloys used are not machinable. They are strong and stiff at high temperature, consequently forging is difficult and costly. Investment casting has not only produced these parts in quantity, but has accelerated the development and production of jet engines at a far more rapid rate than conventional methods would have permitted.

One of the unique features of the investment casting process is the short time required to get parts, once a pattern is made. In cases of extreme emergency, this has been done in a matter of days. Ordinarily, of course, such heroic service is not available because of disruption to production schedules, but the time required for tooling up is much less than for alternative methods of manufacture, and with considerably lower costs. This feature makes it especially important in fields where designs are still in rapid development, or where various cast alloys are being tested for their suitability in particular parts.

It should be remembered that investment casting became of industrial importance because of its ability to produce large quantities of small parts, accurately and economically, from alloys difficult to fabricate by pre-existing methods. Its advantages diminish as the size and weight of the part increase, and with metals that are readily fabricated by other processes.

Table II — Uniformity of Tests From Successive Heats

Heat	Ultimate	0.2% Offset	Elong. in 1 In.	Red. in Area	Hardness C Scale
1	125,000	100,500	15.6	47.0	25.5
	128,400	101,500	17.2	45.5	25.5
	128,400	101,800	15.6	38.5	28.5
2	117,800	92,500	20.2	45.5	26.0
	118,200	92,000	20.2	41.0	25.5
	117,600	92,500	20.2	39.2	26.0
3	112,800	84,300	17.2	45.0	20.5
	110,800	80,800	17.2	53.0	24.0
	106,400	82,000	15.6	55.0	25.0
4	137,200	105,600	14.0	41.0	28.0
	144,000	115,800	14.0	39.0	32.5
	136,800	111,600	14.0	41.0	27.0
5	122,600	91,000	15.6	41.0	27.5
	118,400	89,400	15.6	49.0	25.0
	121,800	91,000	18.6	51.0	27.0
6	110,800	81,000	20.2	55.0	23.0
	111,200	78,400	18.6	39.0	23.0
	109,200	79,600	21.8	53.0	24.5

The question of over-all conservation of scarce metals should also be considered. While the net yield of castings from a given weight of alloy may seem to be low, the over-all recovery in material is very high.

In the indirect arc casting machine with its protective atmosphere, there is hardly a measurable melting loss, and the recovery on remelting of scrap for making master heats is also high. On the other hand the yield from a cast ingot, after it has been forged, chipped, rolled and cropped, is usually on the order of 65%. Either drop forging or machining and grinding also entail further high losses in scale, chips and grindings. Comparative studies will show a very great saving of scarce and costly alloys by investment casting.

Accompanying illustrations (Fig. 3 and 4) show only a few of the parts that are being cast in some of the alloys referred to in the text.

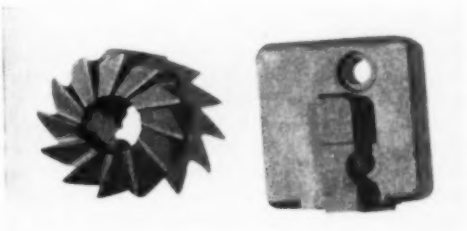


Fig. 4 — Milling Cutter of High Speed Steel and S.A.E. 2340 Part for Cardboard Fabricating Machine

By F. Poboril
Research Engineer
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Ostrava, Czechoslovakia

Resistance of a Gun Steel to Explosive Impact

IT HAS long been understood by metallurgists and engineering designers well grounded in metallurgy that the "toughness" of a steel depends not only on its composition and microstructure (heat treatment) but also upon the velocity with which the loads are applied and the temperature of the metal at the time. More recently the importance of the stress system — whether in one direction or in various degrees of restraint — has also been emphasized. Much study has been given to the many aspects of this situation and to the correlation of test results and service experience. It is my purpose to discuss primarily one feature, the *speed* of loading, and to present some new data to support some practical conclusions.

We have long been interested, at the Vitkovice Steelworks, in the production of high-grade guns. A representative analysis of the barrel steel (and the steel used in the tests to be described) is 0.30 to 0.38% carbon, 1.4 to 2.2% chromium, 1.0 to 1.7% nickel, 0.10 to 0.20% vanadium, 0.30 to 0.50% manganese, 0.20 to 0.40% silicon and 0.04% max. (each) phosphorus and sulphur.

In highly stressed gun barrels having a tensile strength of about 130,000 psi. the toughness values will be low, because tempering cannot be carried out at high temperatures if such a strength value is to be obtained. The best that can be done is to temper for a short time at as high a temperature as practicable. Indeed, the first experiment in the heat treating department made by the author in 1941 on large forgings of chromium-molybdenum steel was directed along these lines. He found that by raising the tempering temperature only 20° C. (from 630 to 650° C., 1165 to 1200° F.) the notched-bar impact resistance of test pieces cut from 20 forgings previously oil quenched or air cooled was increased about one fifth (from an average of 10.3 m-kg. per sq.cm. to 12.6). This short tempering at high temperatures has been called "shock tempering".

It will be noted that "toughness" has been measured in the above paragraph by the notched-bar impact resistance. Although the reduction of area determined by the tensile test is otherwise a quite good criterion of toughness and ductility of steel, it fails completely as a criterion of temper brittleness — something which obviously must be avoided in the alloy steels like the one used for gun barrels.

The sensitivity of the notched-bar impact test for temper brittleness is obviously caused by the notch in the test piece and the higher rate of deformation over that used in tensile testing. However, the velocity of the pendulum of all current impact machines is of the order of a few feet per second. This velocity is too small in comparison with the velocity of deformation of working parts in many engineering and ordnance uses. Since it is known that the values of impact resistance are influenced by the striking velocity, this means that the standardized notched-bar impact machines measure the toughness of the steel only at relatively low rates of loading.

When stresses act very quickly, a machine or structural part which has shown quite satisfactory results in an impact notch toughness test may fail completely.

A few laboratories have been equipped to study the reaction of metals to loading at very high velocities. Notable work, for example, has been done by Prof. D. S. Clark and his associates at California Institute of Technology. Such equipment as installed there is much too complex for routine tests, at present. Consequently the formula proposed by C. Zener and J. H. Hollomon has been

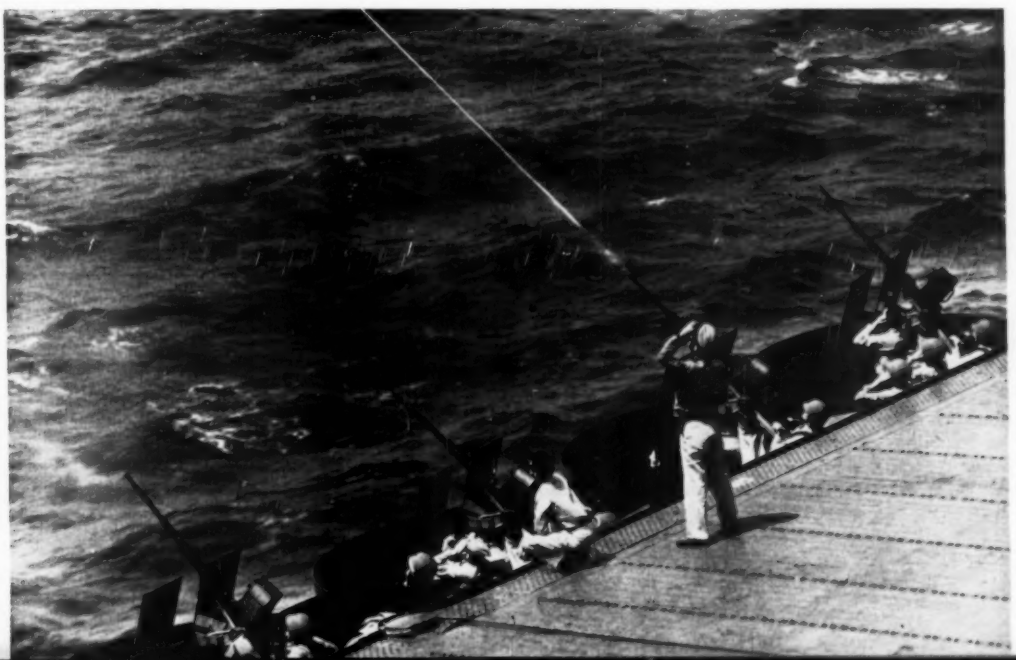
most valuable. It associates, quantitatively, high speed loading and low temperature. Otherwise the difficulties of studying the effect of speed alone would be almost insurmountable. Thus, Zener and Hollomon have stated that in order to reduce the stress by 25% of that value given when the head of the tensile testing machine moves at a speed of 1 in. per min., it should move at a speed of only 1 in. in 100,000 years! On the contrary, to *increase* the stress by 25%, the machine-head should move practically at the speed of light.

Ballistic testing of guns and armor is very expensive and usually the results are qualitative and apply to a single set of conditions, difficult to correlate with other tests of the same kind. Dr. Poboril shows that explosive toughness (measured by the powder charge needed to split a heat treated capsule) has a linear relationship to the Charpy impact of the same steel when tested at −78° C., thus confirming Zener and Hollomon's thesis that the effect of very high speed of impact loading can be replaced by low temperature of a specimen tested at normal speeds.

Up to the second World War, European ordnance officers have met this problem of high speed loading in a pragmatic manner by establishing an "explosion toughness test" for gun barrels. This makes use of shortened, smooth-bore barrels produced from the same material and in the same way as the proper gun barrel. An explosive shell of the proper caliber is then detonated in this cylinder. Materials having satisfactory "explosion toughness" merely deform (or eventually tear apart). Materials of unsatisfactory toughness fragment without substantial deformation.

As a systematic research method this explosion test is too costly. It appeared to the present writer, however, that it had one element of great value — namely, high speed impact — and work was undertaken on simplified test pieces. That having been done, the results of the explosion test were correlated with results of the standard notched-bar Charpy test at room temperature and at −78° C. (−110° F.), and with hardness, tensile strength at room temperature, and so on. I believe that the conclusions are of considerable general interest.

To determine the relation between the notch toughness and the explosion toughness, we used



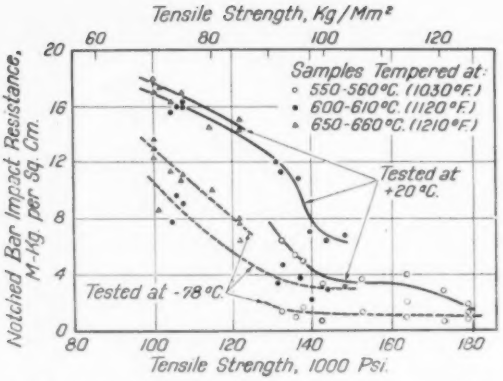
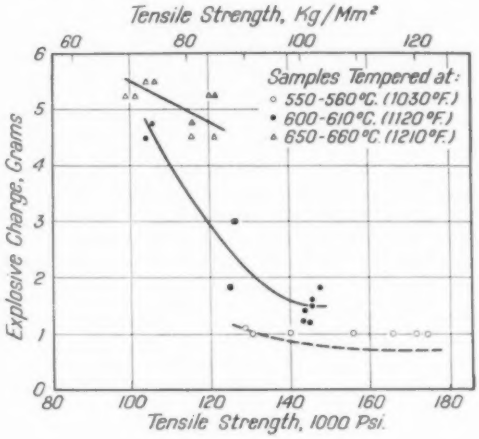


Fig. 1 — Relation Between Charpy Impact at +20° C. and −78° C. and the Tensile Strength of Cr-Ni-V Gun Barrel Steel, Oil Quenched and Tempered. The lower tensile strengths for a given tempering temperature result from a progressively longer tempering time

Fig. 2 — Relation Between Explosion Toughness and Tensile Strength of Gun Steel, Oil Quenched and Tempered for Various Times at Three Temperatures. (Curves for slowly cooled samples of the same steel are substantially equivalent to the ones shown)



the German standard notched-bar, 10x10x55 mm., notch 2 mm. wide and 3 mm. deep with bottom radius of 1 mm. The explosive tests are made with miniature explosion cylinders 60.2 mm. long, 14 mm. internal diameter, 28 mm. external diameter. A measured charge of trinitrotoluene is inserted into this cylinder and exploded by a detonator and an electric igniter. Such steel test pieces are easily made; numerous duplicates were heat treated identically. Explosive charges, ranging in ¼-g. steps from 1.0 to 5.5 g. trinitrotoluene, were then used, starting at a low weight calculated to deform but not to fracture the cylinder. The weight of explosive was then stepped up in succeeding trials until the cylinder would be torn. Either a short or a long tear or more complete fragmentation would mark the end of the test, and the explosive charge required would be noted as the "explosion toughness". All explosive tests were made with the steel cylinder at room temperature.

Both explosion cylinders and impact test specimens were heat treated similarly: Heat 1 hr. at 850° C. (1560° F.) and cool either in oil or in a furnace at a cooling rate of 1000° C. per hr. (0.5° F. per sec.) through the range of 800 to 650° C. Three tempering temperatures were used — 550/560° C., 600/610° C., and 650/660° C. (approximately 1030, 1120 and 1210° F. respectively); tempering times were 1, 3, 12, 36 and 100 hr. All samples were oil quenched from the tempering heat.

Principal results are shown in the four diagrams reproduced on these pages.

Hardness of the tempered specimens (and tensile strength computed therefrom) was not affected by the prior speed of cooling from 1560° F. — that is to say, whether originally oil quenched or furnace cooled. The samples hardened in oil showed a martensitic (tetragonal) structure in the hardened state and a homogeneous sorbitic structure when tempered. The samples cooled slowly showed a bainitic structure in the hardened state and a heterogeneous sorbitic structure when tempered. The furnace cooled samples were measurably poorer in Charpy impact values when tempered samples of equal tensile strength are compared. On the other hand, the explosive toughness of the slowly cooled samples is quite comparable, as will appear in the sequel.

Analysis of Results

From the curves in Fig. 1 it is to be seen clearly that notch toughness at equal strength increases with increasing tempering temperature.

The gain in toughness after tempering at 650° C. as compared with 600° C. (when determined at normal temperature) is quite negligible, but when tested at −78° C. it is very important. All values after tempering at 550° C. are quite inferior.

A further characteristic difference can be seen in the course of the curves. When testing at 20° C. the transition from the tough to the brittle region occurs at the strength range of 125,000 to 140,000 psi., whereas at −78° C. this transition occurs in

Fig. 4 (at Right) — Same Relation as in Fig. 3, Except the Samples Were Slowly Cooled and Then Tempered

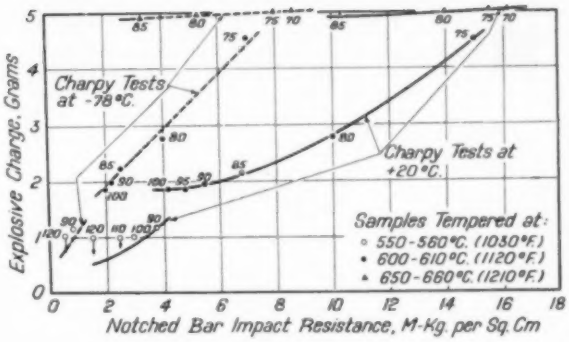
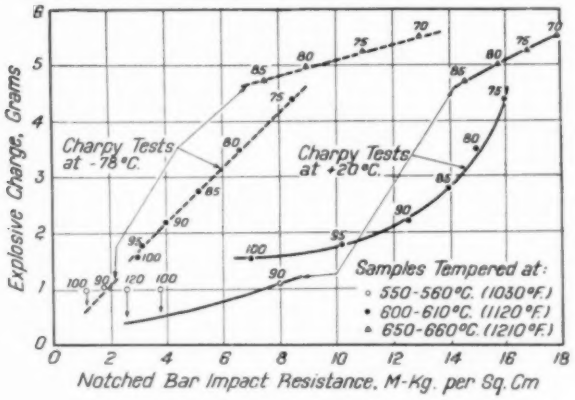


Fig. 3 (Below) — Relation Between Explosion Resistance and Notched-Bar Impact Resistance at +20° C. and −78° C. for Cr-Ni-V Gun Barrel Steel, Oil Quenched and Tempered. Figures represent approximate tensile strength in kg. per sq.mm. (1 kg. per sq.mm. = 1422 psi.)



considerably weaker metal — below 100,000 psi.

Examining now the relationships between explosive charge required to rupture and the tensile strength (hardness) of the oil quenched steel (Fig. 2), and comparing them with the curves of notch toughness in Fig. 1, the similarity is obvious, particularly the curves for notch toughness at −78° C. Figure 2 may represent substantially the condition for slow cooled steel, as well.

The curves in Fig. 3 and 4 were constructed to determine the quantitative relation between explosion toughness and notch toughness. The individual points marked on the diagram have been taken from curves connecting plotted points and therefore represent values obtained by graphical interpolation.

It is evident that the dependence between explosion toughness and the notched-bar impact energy at +20° C. is linear only for samples heat treated for high toughness (tempering temperature 650° C.), but not for samples heat treated for higher hardness (tempering temperatures 600 and 550° C.).

On the other hand, the relation between explosion toughness and specific impact energy (Charpy test) at −78° C. is linear with *all* the samples tested.

The latter fact is also demonstrated if samples of equal strength are selected and the relation between explosion toughness and Charpy toughness is plotted for these various strength levels. Again we find that the relation beween the explosion toughness and the specific impact energy is linear only for the values obtained in notch toughness tests at low temperature, a conclusion that harmonizes exactly with Zener and Hollomon's thesis that high impact velocity and low temperature both affect the toughness value in the same way.

From the standpoint of ballistic testing an important conclusion also follows, namely, that the so-called explosion tests can be replaced by notched-bar impact tests at low temperature.

The technological advantages of notched-bar impact tests are evident; the most important one is that the dimensions of the samples are smaller, thus enabling the use of a large number of test samples from the same quantity of material.

Furthermore, the explosion tests are subject to many influences which can affect the test results adversely. For example, in large forgings the original location of the sample can have a decisive influence on the results, the samples taken from near the external surface usually giving much better results than those taken deeper inside. (Near the inside surface there is an accumulation of segregates.) The differences in the brisance of the explosive charges, caused by density deviations of charges or detonators, are a further source of errors occurring with explosive tests.

A further disadvantage of the explosion test is that it gives only qualitative information on the explosive toughness of the single material; impact tests, however, give quantitative numerical values useful to the metallurgist and the designer.

Ultramodern Supersonics and X-Rays

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MAGNETIC investigations at the Naval Ordnance Laboratory at White Oak, Md., just across the northern boundary of the District of Columbia, has been briefly described by the Editor of *Metal Progress* in the April issue. The entire establishment, with its 60 permanent buildings and 2300 employees, is concerned with the improvement of guns, mines, missiles of all sorts and their guidance, and detection of the enemy. To fulfill this task, its facilities and investigations are exceedingly diverse. Not the least of these are devoted to nondestructive testing, and the dedication of the million-dollar X-ray laboratory was an event that warranted attendance of those who are interested in latest ideas in this field.

At the outset, Dr. C. S. Piggot, consultant to the Navy's Research and Development Board, emphasized the great importance of special applications of nondestructive testing, such as radiography, as a preliminary to the disposal of enemy mines, but he also stressed the importance of an advanced laboratory such as this to the metals industries, particularly in wartime mobilization. The part played by nondestructive testing in forward movements among all branches of the armed services (as consumers) and throughout the metal industries (as suppliers) was given more detailed attention at a formal session when experts spoke on its applications in the manufacture and testing of steel castings, weldments, and magnesium products, and on various kinds of mass production inspection.

Among the new X-ray and other nondestructive testing facilities demonstrated was a 10-million electron volt mobile betatron and a 2-million electron volt resonant X-ray generator. These are mounted on bridge cranes in a room with reinforced concrete walls 3 ft. thick. The arrangement is shown in Fig. 1. (Medium and low-voltage X-ray equipment is housed in smaller concrete cubicles.)

Use of Mobile Betatron

The smaller machine is of a design that has been available since early in World War II, and it is well known to inspectors of heavy equipment. The 10-million electron volt betatron, however, is probably the first of its kind to be used in mechanics and metallurgy, although first cousin to equipment used for "atom busting" by theoretical physicists. It consists of a toroidal electromagnet surrounding a doughnut-shaped vacuum tube in which bursts of electrons are accelerated to very high speeds and then diverted to hit a tungsten target, from which the highly penetrating X-rays emerge. The fundamental principle, of course, is exactly the same in both machines; in the smaller machine stemming from the 1941 design, the accelerating tube is straight, axial to the casing.

The advance beyond previous laboratory applications was typified by the studies of internal clearances now made possible by this mobile betatron. It can be swiveled so it can send a beam of rays at any angle into an engine, or any other machine while it is running. Steel channels are mounted in the floor and walls to facilitate the mounting of such machines. This provision is particularly important when new alloys are being used in jet engines before their high temperature properties are known.

Ultrasonic, fluorescent penetrant and magnetic particle inspection methods were demonstrated, in addition to the X-ray equipment. Mechanical testing and metallurgical laboratories were shown to be essential aids in the correlation

of indications obtained with nondestructive methods. Invited exhibitors added to the show by bringing the latest developments in microflash equipment, an electronic fluoroscope, an X-ray movje camera, and some new materials for electrostatic particle inspection.

Electrostatic particle inspection is a recent development of the Magnaflux Corp. and is patented under the name of "Statiflux". It applies a basic law of physics using very fine particles which are ejected from an atomizer in such a manner that they are positively charged. Such particles may be sprayed onto semiconductors, such as enameled kitchenware. Since any tiny crack in the enamel provides a source of electron leakage, the particles lose their positive charges at the crack and build up a pattern. Figure 2 shows fine cracks in a pottery glaze. If a nonconductor is to be inspected, it must be immersed in a warm electrolyte and the latter dried on the surface prior to the test. Cracks smaller than 4000 Angstroms in width (below the limits of the optical microscope) have been detected.

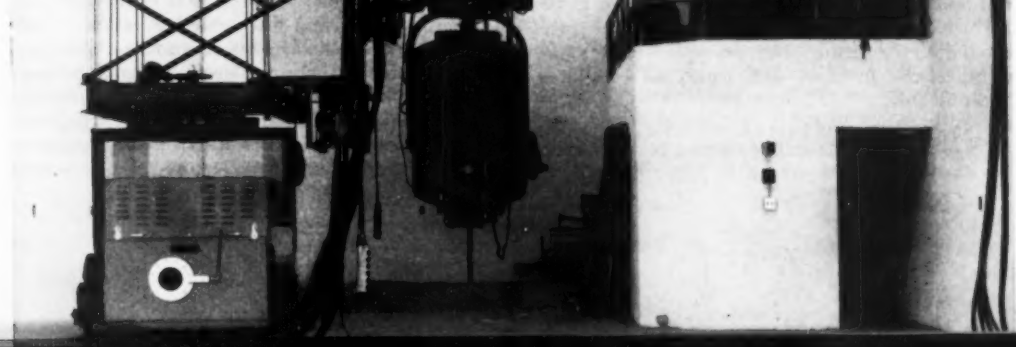
Improved Fluoroscopes for Inspection in Production

The meeting included a symposium on techniques, the first session being devoted to information about the development of much of the equipment mentioned above. The advantages and limitations described imply certain interesting industrial applications.

F. H. Marshall of Westinghouse Research Laboratories discussed the electronic X-ray fluoroscope. Images 500 times as brilliant as those obtained with standard fluoroscope screens are produced, but the sensitivity is of the same order —namely, 6%. Figure 3 shows the principle; X-rays which have penetrated the object under study impinge upon the fluorescent screen at the left, and the light emitted causes electrons to be ejected from the photo-electric substance placed on the concave surface in contact with the fluorescent screen. These photo-electrons are accelerated across the tube by an externally-applied potential of 15 kilovolts. When they strike the phosphor layer at the right-hand end, an image is formed which would be the same size (if not focused) but 20 times as bright as the original screen image. To further increase the intensity of the final image, the photo-electrons are focused by means of electrostatic lenses which invert and reduce the image size five diameters, thereby increasing the brightness 25 times, and giving a total increase in intensity of 500 times. When this real image is observed through a compound eyepiece, the brightness is retained and the image reinverted and returned to life size.

A paper on electrostatic X-ray generators by

Fig. 1 — View Through Open Portal of Cell Containing 10,000,000-Volt Betatron (Left Foreground) and 2,000,000-Volt Resonant Generator X-Ray Machine (Central Rear). Power supply is on mezzanine floor (upper right). Cell has concrete walls, 3 ft. thick, and is placed in the center of a building, flanked on either side by smaller cubicles containing low-voltage X-ray equipment



D. Robinson reported the High Voltage Engineering Co.'s portable 2,000,000-electron volt generator to be available with a 32-in. pump-type tube. Magnetic focusing to an effective focal spot of 0.01 in. and an output of 100 Roentgens per min. at 1 in. should make this machine very useful to the steel industry as an inspection tool. By comparison with the older, stationary generator of the same voltage, one could estimate that 4 in. of steel would require only 1 min. exposure to obtain a radiograph with 1% sensitivity. At half the length and one third the weight of the first Van de Graaff generator, it should provide an adaptable and rapid inspection service for manufacturers of heavy steel castings, armor plate, or weldments of very thick section.

The X-ray cinematograph shown by C. M. Slack of Westinghouse Electric Corp. revealed the internal goings-on during a thermit welding operation, wherein convection currents and density changes were quite apparent.

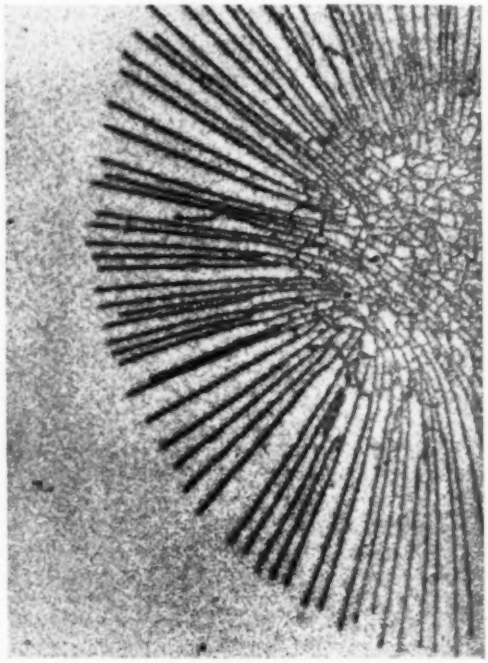
New Uses for the Reflectoscope

F. A. Firestone, consultant to Sperry Products, Inc., described many tricky applications of the "Reflectoscope", including some which have not reached the stage of industrial application.* Detection of fatigue cracks in locomotive axles is well known. Grain size measurement of copper was shown to be possible. Interesting means exist for determining internal conditions such as carburization and residual stress by measuring the velocity of waves through various regions of the piece.

The "angle crystal" has many possibilities for reaching inside the body of articles whose exteriors are poorly adapted for the normal quartz crystal resonator and receiver. The "angle crystal" is merely the useful quartz crystal mounted in a special holder. Instead of being placed flat against the surface to be tested, the crystal is held in a swiveling mount inside a cup of mercury. The cup is closed by silver foil, amalgamated for good contact with the mercury and transmission of the impulses. By moving the crystal to the proper angle (noted by appropriate verniers) a beam can be sent into the mercury at any desired direction and it is transmitted through the silver foil and into the work at an oblique angle to the surface. Waves started in this manner can travel around a large drum — for example — by a series of internal reflections, and report on conditions encountered.

*See also his 1948 Mehl Lecture before the Society for Nondestructive Testing, published in *Nondestructive Testing*, Fall 1948 issue, p. 5.

Fig. 2 — Pattern of Submicroscopic Cracks in Semiconductor (Enameled Kitchenware) Shown by "Statiflux" Inspection



Applications to Metallic Objects

The second session on techniques related largely to metal production and fabrication. C. W. Briggs of Steel Founders' Society of America traced the history of steel casting inspection from the hammer tests prior to 1925 to the present day's X-ray specifications enforced by the Navy. He emphasized the need for standards for magnetic particle inspection to supplement the specifications requiring that test. H. H. Lester of Watertown Arsenal, a long-time proponent of individual rather than universal standards, conceded that the latter could be useful in raising the quality of a product, as long as it was not forgotten that even a crack is not a rejectable defect if it will be under compression at all times in service.

Kent R. Van Horn of Aluminum Co. of America stated that ultrasonic inspection is used as a routine method by his organization for examining aluminum blooms, press stock, and heavy pieces, and Alcoa's standards allow only fissures less than 0.020 in. which have proven to forge out. The method will also detect chromium segregates as small as 0.020 in. in 75S alloy. The sensitivity

of the sonic method is 0.1% through 15 in. of aluminum alloy. As for nondestructive testing in general, Dr. Van Horn believes much of value could result from some coordinated thinking by all government agencies, particularly comparing the acceptance tests with the extensive service records on hand at the Air Materiel Command.

O. R. Carpenter of Babcock & Wilcox Co., in commenting on radiography of pressure vessel weldings, pointed out the need for applied research on the nondestructive testing methods aimed toward an answer to these questions:

1. What are considered to be acceptable nondestructive test methods and where should they be applied?
2. In what order are the methods to be preferred, in each instance?
3. What defects can be shown, and which of them have the most important effect on service reliability?
4. How can the service strength be correlated with nondestructive tests?
5. How can this information be properly obtained by the seller, purchaser and inspector?

Mr. Carpenter feels that it is often important to have an accurate stress analysis of the over-all structure, so that time will not be wasted in a critical inspection of a particular weld which may be at a point of low stress. He warned against repeated magnetization and demagnetization of a single region in a welded structure; such treatment will give rise to a broad indication in the absence of any discontinuity. In order to expedite emergency manufacturing of ordnance, he is of the opinion that a revised inspection manual is needed — to be kept up to date, to classify design, to recognize proper places to inspect, and to include a code of performance for inspectors. (W. R. Papst of the Bureau of Ordnance stated that a manual for pre-planned inspection is underway.)

Applications of nondestructive testing by the magnesium industry were described by J. C. McDonald of Dow Chemical Co. He emphasized two points relative to the inspection of light alloy castings, particularly of magnesium:

First, surface inspection (visual) is extremely important. Fluorescent penetrants are helpful for making sure that the piece has had a proper solution heat treatment. (However, this is better checked by lightly polishing and then etching a spot, transferring the surface pattern to a plastic, removing the plastic film and observing it under a microscope.) Second, he was firm in his belief that microshrinkage in magnesium castings, as revealed by X-rays, does not correlate with unusually low results of tensile or rotating beam tests.

Failures in service have shown that the fatigue cracks ignored the presence of microshrinkage. This condition is caused by the molten metal flowing in channels rather than on a broad front; the extra heat brought in produces hot spots in the adjoining sand, and the metal nearby freezes last, concentrating the microshrinkage. It is possible to minimize this condition by proper risering and gating, but the design engineers must tell the foundrymen where the points of high stress are — or, better yet, eliminate them.

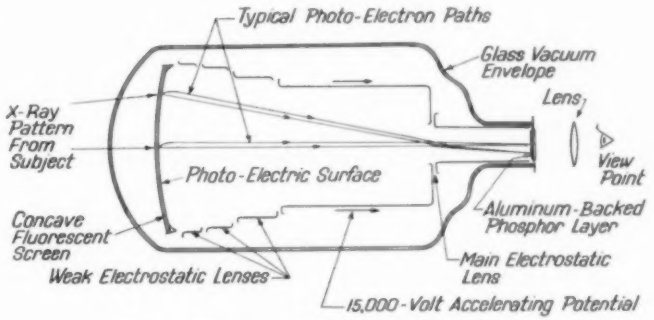


Fig. 3 — Diagram of Electronic X-Ray Fluoroscope

J. J. Pierce of Naval Ordnance Laboratory emphasized that any agency attempting to establish nondestructive testing methods applicable in industry simply *must* have a great amount of information about industrial mass production. He cited examples of how X-rays were applied to quantity inspection in aircraft castings on the West Coast, to welds of storage tanks at Hanford, Wash., and to rocket propellants at the Naval Powder Factory, Indian Head, Md., during the war, saying that these routine inspections were made without reducing the sensitivity obtainable and possible by the test method.

In a discussion of the current and proposed military applications of nondestructive testing, J. C. McGee, U. S. Air Force Materiel Command, made some comments of interest to the metallurgist. He mentioned that less and less steel is expected to be used in aircraft. The Air Forces use the reflectoscope to inspect jet engine forgings — not for soundness so much as to check upon the manner of forging. They also find the "angle crystal" technique well adapted to the inspection of propellers and impellers.

Should Radio-Isotopes Be Exported ?

A DECISION on Aug. 19, 1947, by the Atomic Energy Commission (Commissioner STRAUSS dissenting) to make radioactive isotopes up to element 83 (bismuth) available to properly accredited research scientists in foreign countries, followed a favorable opinion as to its propriety by the General Advisory Committee* and as to its legality by the Commission's general counsel. The General Advisory Committee stated on June 8, 1949: "We have re-examined the statement and wish to reaffirm our conviction that these recommendations constitute sound policy."

The following is abstracted from the original statement dated June 1, 1947:

These radioactive isotopes are very valuable tools for research in chemistry and biology and in treatment of certain diseases. A plan for making them available at cost to U. S. scientists for research purposes was announced a year ago. They will be equally valuable to scientists and medical men abroad and the research done with them will benefit all mankind.

In these days when the restoration of free science and the building up of good will among people is so vital, it is essential that the United States should share its new tools for research and therapy, and thus prove that this country will do all it can, consistent with its own defense and security, to improve the public welfare and raise the standard of living throughout the world.

The quantity of radioactive materials to be made available is extremely small. They are not useful for military or industrial employment of atomic energy, and cannot constitute a danger to world peace or to the security of the United States. Also the foreign distribution will not interfere with an ample supply for U. S. scientists.

The conditions under which these materials will be sold are such that diversion to secret or military research will be difficult and any continued diversion of this sort will be impossible. Such supplies cannot accumulate, since they are mostly of relatively short life and they are expended in the experiments themselves beyond practical recovery.

The radio-isotopes available were well known to scientists before the war and can be produced in small amounts by standard instruments such as cyclotrons. However, it is a very great service to have quantities available immediately.

Under all these conditions the beneficial results of the program will be great in terms of good will, and it may assist distinguished foreign scientists abroad who work in open laboratories to make important discoveries of benefit to all.

Commissioner Strauss Dissents

In a statement to the Joint Congressional Committee of the Congress on June 9, 1949, LEWIS L. STRAUSS, member of the U. S. Atomic Energy Commission, said that the question of whether indiscriminate dissemination of knowledge on atomic energy ought to be made during the period of a cold war is the real point at issue. He also recalled the reasons for his dissenting vote on the proposal to make radioactive isotopes available to foreign scientists. The official minutes of that meeting of the Commission (Aug. 19, 1947) have been made public, and the following is an abstract of the portion concerning his views:

"Mr. STRAUSS stated that the staff memorandum on this subject did not convincingly meet certain basic objections which he felt should be controlling in this matter. Until the satisfactory international control of atomic energy is secured, the United States should take no steps that might help scientists who may work for a possible enemy nation. He expressed doubt that it would be possible to buy the good will of foreign scientists by authorizing the distribution of radio-isotopes abroad. In connection with the point that our release of radio-isotopes will merely make available what those countries will eventually obtain through their own efforts by the use of cyclotrons already existing abroad, he pointed out that cyclotrons produce submicroscopic quantities of radio-isotopes and that, to obtain amounts comparable to production in our piles, thousands of cyclotron-years would be required. He also expressed doubt that the restrictions to be placed on shipments abroad could effectively prevent their use for unfriendly purposes or their divergence to unfriendly hands which might endanger our national security. Mr. STRAUSS stated that he did not contest the point that the isotopes in question could not be used by other countries to produce atomic weapons, but felt that they would be useful as tools in biological research, metallurgical research, petroleum chemistry, and other areas which are a part of the war-making potential of nations.

"Mr. STRAUSS also believed that the language of the McMahon Act is clear when it states 'that until Congress declares by joint resolution that effective and enforceable safeguards against the use of atomic energy for destructive purposes have been established, there shall be no exchange of information with other nations with respect to the use of atomic energy for industrial purposes'" [and that this prohibition in a law, which the Commission is charged to execute, must obviously presume the greater prohibition of exchange of information or materials of possible military use].

*The membership is as follows:

Chairman: J. ROBERT OPPENHEIMER, wartime director of Los Alamos Laboratory; now director of Institute for Advanced Study, Princeton, N. J.

Members: OLIVER E. BUCKLEY, president, Bell Telephone Co.; JAMES B. CONANT, president, Harvard University; LEE A. DUBRIDGE, president, California Institute of Technology; ENRICO FERMI, professor of physics, Institute for Nuclear Studies, University of Chicago; I. I. RABI, chairman, Department of Physics, Columbia University; HARTLEY ROWE, vice-president and chief engineer, United Fruit Co.; GLENN T. SEABORG, professor of chemistry, University of California; CYRIL S. SMITH, director, Institute for the Study of Metals, University of Chicago.

A New Low-Alloy Steel for High-Temperature Use

By George F. Comstock
Assistant Director of Research
Titanium Alloy Mfg. Division
of National Lead Co.
Niagara Falls, N. Y.

A LOW-CARBON STEEL with extraordinary hardness and stress-rupture properties after quenching and reheating at high temperatures has recently been discovered in the laboratories of the Titanium Alloy Mfg. Division of National Lead Co.* This development is still in a preliminary stage; no commercially-produced stock has yet been made or tested, but patent protection has been applied for.

The discovery was made in a search for a simple, inexpensive alloy addition that could be used in low-carbon titanium steels to prevent coarsening at temperatures above 1625° F. Boron additions up to 0.10% were not successful for the desired objective, but it was discovered that the hot shortness normally to be expected[1] was absent. With boron above about 0.01% these steels hardened very appreciably by quenching or even air cooling from 2100° F., and retained an exceptional degree of hardness after tempering.

The steels whose properties are reported herein were melted in a 30-lb. high-frequency induction furnace and thoroughly killed with aluminum before additions of boron and titanium in the ferro-alloy form. The ingots were forged or rolled to bars at various shops without any special difficulty. As a matter of convenience, most of the hot work was done below 2050° F. Carbon was kept low to avoid the necessity for too much titanium for stabilization or "carbide control". Compositions are shown in Table I.

The forgeability of these steels, which contained enough boron to produce hot shortness, is apparently related to the fact that sufficient titanium was present to combine with the carbon. Evidently it is not boron or a boride that promotes hot shortness, but an iron-boron-carbon eutectic which melts at ordinary forging temperatures. With the carbon fixed as titanium carbide this fusible eutectic is not formed.

It is evident from Fig. 1 that either titanium or columbium, but not zirconium, can be used with boron to harden these low-carbon steels, and provides much greater hardness than by similar treatment with titanium or boron alone. Holding at the hardening temperatures more than 30 min. did not alter the values, and raising the temperatures higher than 2100° F. was of no consequence.

Rate of cooling from the quenching temperature (2100° F.) is of much less importance in the Ti-B steel than the plain titanium steel:

	Steel No. 2 (Ti-B)	Steel No. 1 (Ti)
Water quenched	B-101	B-94
Air cooled	B-93	B-64
Cooled in "silocel"	B-86	B-44

Figure 2 indicates that there is generally a slight gain in hardness after tempering at 1000 to 1100 or 1200° F., but this temper hardening is negligible compared with the hardness developed on cooling from the high temperature. For steel A of Fig. 2 (No. 3 of Table I) 1900° F. is too low a hardening temperature, although this was not true of the titanium-boron steel of quite similar analysis in Fig. 1. There is a definite loss in hardness of fully hardened specimens when the tempering temperature is raised to 1300° F.

It is believed that the hardening of these ferritic titanium-boron steels is thus similar in

*The thanks of the author are due to numerous associates contributing major portions of the work involved in this investigation, notably S. F. Urban, R. S. Stewart, A. S. Yocco and C. T. Cessna; also to J. W. Freeman of the University of Michigan for the rupture tests.

Table I — Analyses of Ti-B Steels Investigated*

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
C	0.03	0.034	0.039	0.035	0.035	0.03	0.06	0.06	0.06	0.07	0.07	0.07
Mn†	0.22	0.23	0.32	0.34	0.33	0.19	0.41	0.44	1.29	1.36	0.51	0.5
Si	0.09	0.09	0.11	0.10	0.10	0.12	0.29	0.23	0.44	0.55	0.41	0.4
Ti	0.28	0.30	0.36	0.24	0.19	0.32	0.30	0.24	0.38	0.49	0.32	0.33
B	None	0.026	0.025	0.012	0.029	0.018	0.025	0.02	0.02	0.03	0.02	0.02
Cr	—	—	—	—	—	—	2.82	6.14	18.08	17.51	2.2	2.2
Ni	—	—	—	—	—	—	—	—	10.91	11.35		
Mo	—	—	—	—	—	—	—	—	—	—	0.51	1.05

*Phosphorus and sulphur were both below 0.05% in all these heats.

†It is believed that manganese above the usual residual content of about 0.15% is unnecessary, since titanium in the amounts employed will prevent hot shortness due to sulphur.

principle to the martensitic hardening of carbon steels.* The degree of hardening of the former is obviously much less intense; another notable difference is that the effect is not dependent on rapid quenching. Furthermore, tempering between 900 and 1200° F. moderately raises the hardness.

Room Temperature Properties

Tensile properties of two representative steels are illustrated in Table II. The strength is about doubled after hardening and tempering, with little loss in ductility (reduction of area).

Notch sensitivity is rather high in the condition of maximum hardness (see steel No. 3 of Table II), but notched-bar impact values can be improved either by hardening from a little below that giving the maximum hardness, or (better) by tempering at a temperature sufficiently high to decrease the hardness slightly. This is illustrated in Table III.

Notch sensitivity of these hardened steels seems to be a property of the ferrite and is not related to any change in grain size or microstructure so far discovered. For instance, a ferritic titanium steel without boron was given the same heat treatment as in the fourth line of Table III (air cooled from 2100° F., tempered at 1000° F.) and had an Izod value of about 140 ft-lb.; its ferrite grain size was 70% No. 1 to 3 and 30% No. 4 to 6. Steel No. 2 in Table III after this heat

Table II — Room Temperature Properties of Ti-B Steels

Property	Steel No. 2		Steel No. 3
Air cooled from	1600° F.	1800° F.	2100° F.
Tempered at	Not tempered	1000° F.	1200° F.
Hardness	B-40	B-46	B-85
Yield strength, 0.2% offset	31,000 psi.	—	70,300 psi.
Tensile strength	44,700	—	84,400
Elongation in 2 in.	44.0%	—	21.0%
Reduction of area	85.7	—	79.0
Izod impact value	—	115 ft-lb.	24 ft-lb.

*The Editor and the author had a spirited argument on this point (a mental exercise about a strictly theoretical matter) when this paper was read at the Western Metal Congress, the Editor holding that the heat treatment data indicated precipitation hardening. Mr. Comstock agreed that the heating at about 2000° F. could be regarded as a solution treatment, but the metal should be "soft" after cooling from this temperature. The Editor held that "soft" was a relative term; the characteristic of precipitation hardening is an *increase* of hardness upon tempering and this is shown by the steels of Fig. 2; the characteristic of a martensitic reaction is a *softening* after tempering — except in the very earliest stages. Lacking contrary evidence from microstructural or X-ray study, the datum (B-50, B-100, or whatever) does not matter — at least in the Editor's view.

Table III — Izod Values Improved by Sacrificing a Little Hardness

Air Cooled From	Tempered At	Steel No. 2	Steel No. 3	Steel No. 4	Steel No. 5
1800	1000	B-46, 115 ft-lb.	—	—	—
1900	1000	B-84, 17 ft-lb.	B-45, 119 ft-lb.	—	—
2000	1000	B-92, 6 ft-lb.	B-83, 21 ft-lb.	—	—
2100	1000	B-92, 5 ft-lb.	B-90, 10 ft-lb.	—	—
2100	1100	—	B-87, 12 ft-lb.	B-93, 4 ft-lb.	B-96, 5 ft-lb.
2100	1200	—	B-85, 24 ft-lb.	B-85, 15 ft-lb.	B-85, 15 ft-lb.
2100	1300	—	B-73, 151 ft-lb.	—	—
2200	1300	—	—	B-80, 146 ft-lb.	B-84, 154 ft-lb.

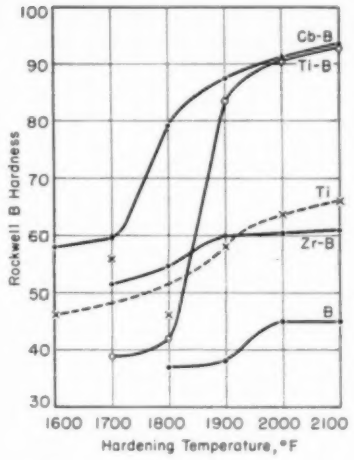


Fig. 1 — Ti-B and Cb-B Combinations Effectively Harden Low-Carbon Steels; Zr-B Is Not Nearly So Potent — Nor Is Titanium or Boron Alone. Small specimens were air cooled from indicated temperatures. Curve marked Ti-B is for steel No. 2 of Table I

Curve Designation	Steel Composition C	Mn	Si	B	Ti	Cb	Zr
B	0.034	0.17	0.01	0.025	-----	-----	-----
Ti	0.062	0.30	0.11	------	0.33	-----	-----
Ti-B	0.034	0.23	0.09	0.026	0.30	-----	-----
Cb-B	0.044	0.35	0.41	0.016	-----	0.78	-----
Zr-B	0.045	0.37	0.33	0.019	-----	-----	0.44

treatment had an Izod value of only 5 ft-lb. with almost the same microstructure, the ferrite grain size being 60% No. 1 to 3 and 40% No. 6 to 8.

Additions of nickel (up to 2%) may be slightly beneficial to the notch toughness of the steels at maximum hardness, but manganese (up to 1.6%) and chromium (up to 4.8%) seem to be detrimental to toughness.

Rupture Strength at Intermediate Temperatures

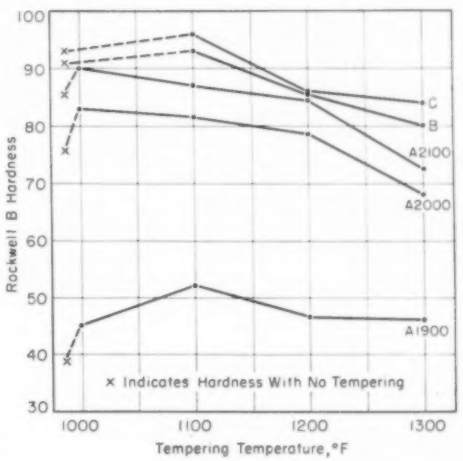
A rather large number of stress-rupture tests between 1000 and 1200° F. have been completed. The top section of Fig. 3 shows the results at 1000° F., and marked superiority of the titanium-boron steel to the carbon-molybdenum steel now commonly used for service at that temperature.[2] Specimens were quenched and tempered, but (as has been noted above) air cooling would probably have made little difference. All specimens elongated 10 to 22% before rupture.

Stress-rupture tests at 1100° F. show outstanding results. Some of these are shown in the middle strip of Fig. 3, where the short broken lines refer to steels No. 3 and 6 of Table I. These specimens were air cooled from 2100° F. and tempered at 1000° F., and showed 14 to 22% elongation. The steep slope of the dotted lines suggests that over-tempering may have occurred (the test was at 1100° F.), but may also have been due to reduction of the specimen size by oxidation.

For long service at 1100 or 1200° F. it was felt that the steel should contain some chromium to improve the resistance to oxidation, and a systematic series of tests at 1100° F. was carried out on the 2.82% chromium steel No. 7. Results are plotted as the full line on the central section of Fig. 3. Elongations varied from 12 to 35%. The points are rather scattered, and do not permit extrapolation beyond 1400 hr.; however, a rupture strength of 30,000 psi. for 1000-hr. life at 1100° F. seems fairly well established. This is far above the reported strength of any other ferritic steel under these conditions, even comparing favorably with the reported values for austenitic steels.[3]

The results for this steel tempered at 1300° F. are too inconsistent to permit any definite conclusion, except that this tempering probably produces overaging, and gives inferior results.

A number of rupture tests were made on various titanium-boron steels in different conditions of heat treatment. Testing conditions were set at 1100° F. and 30,000 psi. stress. Tabulation of the results showed that, in these steels, hardness values above B-80 are not a satisfactory indication of good resistance to rupture under stress at high temperature. The stress-rupture values were generally inversely related to the Izod impact values but not directly



Line Designation	Hardening Temperature	Steel Composition C	Mn	Si	B	Ti
A1900	1900°F	0.039	0.32	0.11	0.025	0.36
A2000	2000°F	0.039	0.32	0.11	0.025	0.36
A2100	2100°F	0.039	0.32	0.11	0.025	0.36
B	2100-2200°F	0.035	0.34	0.10	0.012	0.24
C	2100-2200°F	0.035	0.33	0.10	0.029	0.19

Fig. 2 — Tempering Experiments on Ti-B Steels Indicate That 1100° F. Is About Right; 1300° F. Is Definitely Too High. Steels A, B and C are No. 3, 4 and 5 of Table I, respectively

When boron and titanium are added to a soft steel it quenches out to B-85, and this hardness is even increased by long stay at 1100° F. No trace of graphitization was found after 10,000 hr. at that temperature. Stress-rupture tests indicate 1000-hr. life at 1000° F. and 50,000 psi. Boron and titanium (or columbium) additions are also found to improve the stress-rupture properties of 5% chromium steel and 18-8. The text of this article is a shortened version of a paper entitled "Ferritic Low-Alloy Titanium-Boron Steel for Use at Moderately High Temperatures", read before the Western Metal Exposition and Congress in Los Angeles, Wednesday, April 13, 1949.

related to the hardness. None of the titanium-boron steels having long life in the high-temperature rupture tests had Izod values above 25 ft-lb.; conversely, when the Izod value was over 100 ft-lb. the high-temperature rupture life was always short, irrespective of hardness. However, the hardened titanium-boron steels tempered at 1100 or 1200° F. usually gave very outstanding rupture tests with Izod values of about 15 ft-lb. or more.

A few stress-rupture tests at 1200° F. on a 6% chromium steel (No. 8) and two austenitic Cr-Ni steels (No. 9 and 10), all containing boron and titanium, are reported graphically in the bottom part of Fig. 3. Elongation of the ruptured specimens varied from 11 to 42% with one exception (5%). Results on the ferritic 6% chromium steel compare favorably with published values[3] for the much more highly alloyed austenitic steels at 1200° F., while those obtained from the 18-11 Ti-B steels No. 9 and 10 are definitely superior. (An even better result was obtained in a single test of an 18-11 columbium steel with boron, water quenched from 2300° F. and tempered at 1500° F.; this required 816 hr. for rupture at 1200° F. and 40,000 psi.)

Thus there seem to be very interesting possibilities for improving the high-temperature strength of high-alloy steels, at least at moderately high temperatures, by using boron with titanium or columbium, and suitable heat treatment.

Titanium-Boron Steel With Molybdenum

Since molybdenum is the alloy addition now generally used to promote high-temperature strength in ferritic or pearlitic steels, and the titanium-boron combination was found to have

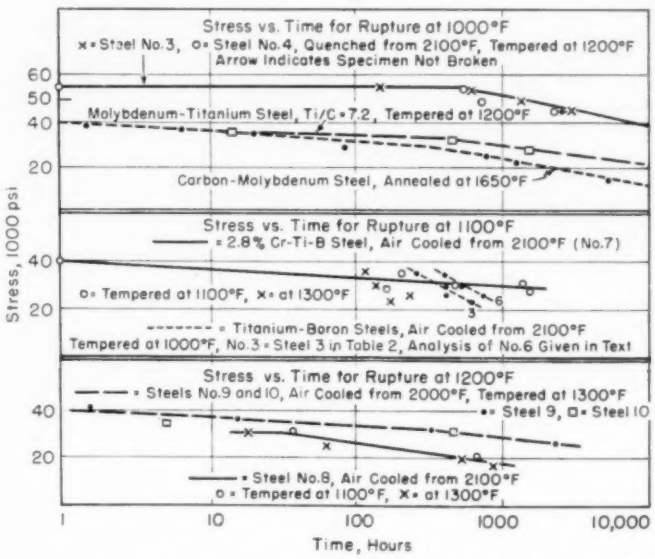


Fig. 3 — Favorable Stress-Rupture Tests Indicate a Utility of Ti-B Steels, Either Low-Carbon or High-Alloy, for High-Temperature Service

References

1. "Boron Steels Increasingly Favored", by N. F. Tisdale, *Iron Age*, V. 151, February 4, 1943, p. 40.
2. "Some Effects of Composition and Heat Treatment on the High Temperature Rupture Properties of Ferrous Alloys", by R. H. Thielemann, *Proceedings* of the American Society for Testing Materials, Vol. 40, 1940, p. 788.
3. "Digest of Steels for High Temperature Service", Timken Roller Bearing Co., Steel & Tube Division, Fifth Edition, 1946.
4. "Carbide Instability of Carbon-Molybdenum Steel Piping", by R. W. Emerson, *Transactions* of the American Society of Mechanical Engineers, V. 66, 1944.

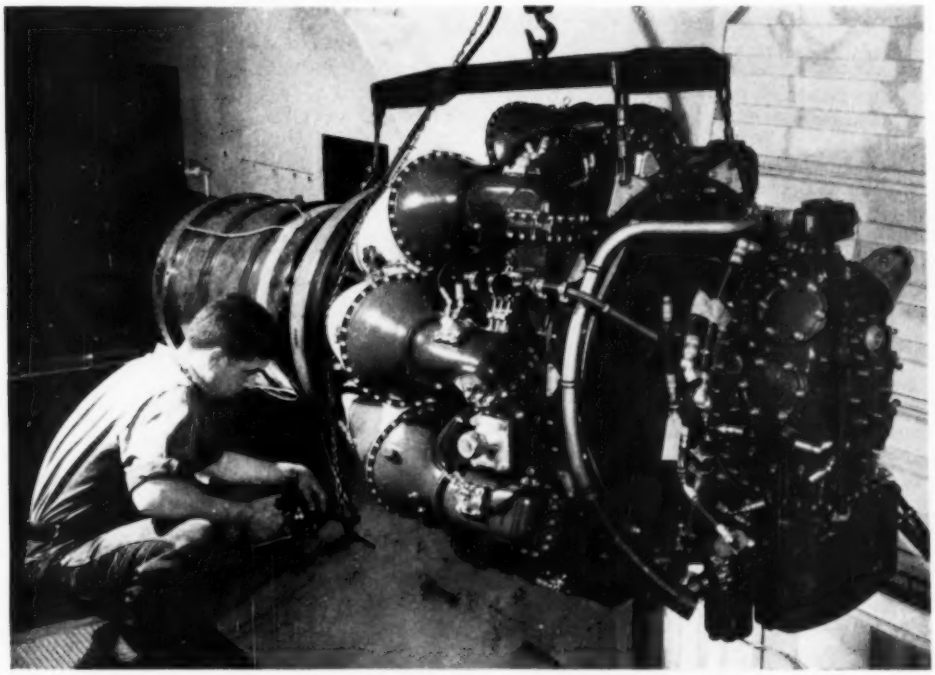
such a remarkable effect in the same direction, two steels were made to see if the effects could be superimposed. Two ingots were poured from the same induction-furnace heat, with an extra addition of molybdenum made after pouring the first ingot. Analyses are shown in Table I as steels No. 11 and 12. Forged sections were heated 1 hr. at 2100° F., air cooled, and tempered 2 hr. at 1100° F., and tested to determine the time for rupture at 1100° F. and 30,000 psi. The test on steel No. 11 was spoiled by instrumental failure after 1022 hr., but the 1% molybdenum steel No. 12 was removed unbroken after 3312 hr. It had elongated 2%.

Comparing this result with that for steel No. 7, it is seen that still greater rupture strength at 1100° F. may be had by using molybdenum with titanium and boron.

Resistance to Graphitization

Stock used for graphitization tests was broken Izod specimens. On some of them Brinell impressions were made to investigate the effect of stress. On others a weld bead was deposited lengthwise. These specimens were stacked loosely inside a small electric furnace. The controller was adjusted to 1100 ±10° F. Specimens of low-carbon steels known to be subject to graphitization[4] were placed alongside to insure that the conditions were correct for graphitizing, but were removed when graphite was found in them.

Specimens have been removed periodically, sectioned through a Brinell impression or through the weld bead, polished, and examined very carefully at high magnification for graphite. The last inspection was after 10,000 hr. and no graphite has been found in any of them except in one doubtful instance *within* a weld bead.



Pratt & Whitney Aircraft JT-63 Turbo-Wasp Engine Which Develops 5000 Lb. Thrust

In conclusion, it is freely admitted that the work here reported is far from complete, and that much more remains to be done to answer many questions that could be asked regarding this development. It is hoped that the data so far obtained may encourage the manufacture of some commercial stock so a larger quantity of this new type of steel may be made available for a more exhaustive investigation.

An Eminent Living Metallurgist



William Benham Price
Director of Research, Emeritus
Scovill Mfg. Co.

Our Biographical Dictionary

WILLIAM B. PRICE is an institution. His retirement from the moil of the mill, with the end of 1947, might well be commemorated with a Milestone which could be inscribed: "Here he paused to rest in the rustling shade, where the waters were sweet and the air balmy."

Things change in the course of 45 years. There are few hereabout who knew Bill when in 1902 he came to Waterbury and got a job as a chemist at Scovill's — even if they can remember so far back. He was a New Haven boy, born there September 22, 1877, which places him. The veterans of the Civil War were still young men. The faintly classical aura shed by Yale College was balanced by the sunset glow of the Wild West, which had not yet faded. Half the plug hats on the street topped the heads of farm boys who had come to town. Here Bill grew up through the gilded age and went to Hillhouse High School in the mauve decade. We regret to put into the record that he sometimes read dime novels with yellow covers. But, happily, he was never apprehended, so no harm came to him. After high school it looked for a time as though he were destined to settle down *in situ*. In 1896 he took a job with his father's firm, Price, Lee and Atkins, Printers, but the Spanish War was in the offing and spring was in his veins. He joined the Navy in '98 and took to the high seas.

A turn of forecastle rations and holystone soon cured him of any visions of grandeur on that tack, and filmed the glamour of iron ships. As soon as he got out he went home and entered Yale, class of 1902 Sheffield, which was not overcrowded with returned veterans. There were great teachers at Yale in those days, too. Horace Wells was in his prime; he had seen service in the steel mills and carried with him something of the wonder of that expanding industry. Treat Johnson was building up his attack on the pyridines and Comstock was brilliantly abstruse. Willard Gibbs was still living and the memory of Silliman was fresh. Bill decided to be a chemist and the die was cast. There was a notable coincidence in the class of '02S, for a slender youth with a long name belonged to it — Champion Herbert Matthewson. The association of these two undergraduates turned out to be more important than could have been foreseen. It is doubtful if even the future professor suspected that he would sponsor more brass-mill technology and technologists than any other teacher of his time. Bill found, as the years unfolded, that a friend of that kind was good to have.

With his diploma safely packed away, and verging on 25, the bachelor of philosophy decided against any more schooling, which in those days would almost inevitably have meant a sojourn in Germany. So he looked about for a job. We have already let the secret out. Up in Waterbury some of the brass mills were hiring chemists, and the Scovill Mfg. Co., which already had a laboratory, presented the opening. The accepting neophyte had never before seen a brass mill!

It is difficult for us in 1949 to imagine the basis on which brass mills had been operated up to about the end of the last century. In the technology of steel, great names had appeared, but no Howe or Fritz had ever been found in a brass mill, even the largest of which was, by comparison, small, localized, and intensely secretive. The compositions of the alloys were kept in the heads (or, perhaps more properly, in the hearts) of the management and, probably, the chief caster. If ever committed to paper they were locked in the deepest vaults and even written in code. There was no way of determining composition, once an alloy was made, except by color, nor any way of knowing the degree of softness or hardness except by appearance, feel, and bending. Men became uncannily skillful with these methods, but the system was coming to be recognized as inadequate.

Even though a broad technical foundation for the industry may not have been visualized, the need of a chemist was obvious. He, in turn, if he had the vision to see where he was, discovered it to be deep water. The course was uncharted, the hazards hidden. The laboratory was in the corner, cluttered with bottles of poisonous mysteries and dominated by a stinking crock of hydrogen sulphide. Under such circumstances some of the young chemists weathered the struggling first years and grew up with the job; that would be Bill, and the job grew, but not so fast.

At first, the function of the chemist was to analyze the alloys, but even the methods of analysis were vague and ill defined. That was one of the first obstacles with which our hero grappled, and set himself the task of clarifying for himself and others. The inclusion of "others" was unique. It would have been more typical of a brass mill of those times to have locked up the analytical procedures along with the book of alloys, and it is greatly to the credit of Scovill Mfg. Co. that it did not. Bill had already shown a flair for his subject. As an undergraduate he had isolated three periodates of manganese, and published his thesis in the *Journal* of the American Chemical Society in 1904. Now he teamed up with Richard K. Meade of Allentown, Pa., and undertook a full and careful connotation of the methods of brass analysis. It was not a minor project.

Plugging hard, with much midnight oil, the thing came out in 1911: "Technical Analysis of Brass" by Price and Meade; John Wiley and Sons.

It was a good, substantial work, timely and useful. It was, for many years, a standard reference. A second, much enlarged edition came out in 1917. Although new tricks of analysis have been devised since that time, and the American Society for Testing Materials has assumed the role of sponsor, the original book is still sound and many of the methods are used today. As for the author, he had emerged from obscurity.

Meanwhile, time had been going and events had not waited upon the passage. In June of 1905 the young man made his way to Cleveland. He really went by train, but it was no secret that he would have walked, if necessary, for he went to be married to Elsie Helen Moore. Arriving again in Waterbury by a circuitous route, they have made their home there ever since.

The year after his marriage Scovill gave Bill the title of Chief Chemist and Metallurgist, which implies that the field of vision was broadening. That "metallurgist" word was something new. The microscope had made its appearance in the brass-mill laboratory and there were indications that the hills about Waterbury would not, forever, supply wood for annealing fires. Oil was coming in; pyrometers were being used and the temperature of the anneal was being correlated to grain size. The composition of alloys was being codified, specified, and generally brought into the light and under control. Ashes from the casting fires were being treated by ore dressing methods to recover the spilled metal. Even the pickle was being tested — to the scornful disgust of many an old mill man, who could have told you the strength of it by the taste! The metallurgist was busy with the physical properties of alloys, too, and their correlation with working properties. He circulated among the customers, determining the cause of failures and designing suitable alloys and tempers. The mystery of season cracking was being unraveled. A technology was being born and it was not a still birth — it was not even quiet! The forces generating it were as broad and lusty as the raucous times of which they were a part.

By the time World War I came upon us, William B. Price was well organized and well known. Besides his book, he had published several technical papers and was ready for the work that fell to him through membership on the Metallurgical Advisory Board of Army Ordnance; Advisory Committee on Metals of the National Academy of Sciences; and the Advisory Committee on Non-Ferrous Metals of the Bureau of Standards and the Bureau of Mines.

In '31 he made a European tour and represented both the United States and the American Institute of Mining Engineers at the International Metallurgical Conference at Zurich, Switzerland. It is not recorded whether he brushed up on his languages. On the same trip, he attended a meeting of the International Assoc. for Testing Materials and, at Milan, represented the American Foundrymen's Assoc. in an international convention. On his return his Alma Mater corrected a 30-year-old oversight, and elected him to the society of Sigma Xi, which must have pleased him. Through it all he was perennially active in American technical and engineering societies, and was a wheel horse in committee work, serving on countless task groups from Abstracts to Zinc Standards, both national and international. In short, the Scovill Mfg. Co. has been represented, in technical circles, by William Benham Price.

Though the days of our lives are legion, the years are few and short; busy with the work that comes to hand, one is always surprised they pass so fast. But we have a suspicion that busy days have been interspersed with moments of relaxation for Bill Price. For, while we never heard that he was fond of hoeing corn, he has been known to break sod with a niblick. Those who know him best aver that there are few who cut a cleaner divot or otherwise surpass him in that ancient game of golf. He plies this avocation at the Waterbury Country Club, but his peripatetic habits are suggested by membership in the State Golf Assoc. and the Senior Golf Assoc.

The infant technology that Bill Price, the graduate chemist, found in the brass mill has grown; the dingy cubicle that was the laboratory has, long since, become a modern institution of service and light. In growing with these things, and being, intrinsically, *of* them, he has had a zestful career. Nothing that can happen to him, in retirement, can change that, and if you ever heard one of his Scottish stories you would not worry. A man like that will get along well enough!

I first knew him as one of that colorful and vigorous coterie that stood at the center of the old American Institute of Metals, in the days before she married her polygamous stepfather and became a Division. There were George C. Stone; William H. Bassett; Wm. R. Webster; Jesse Jones; Nathaniel K. B. Patch; William M. Corse; Guilliam H. Clamer; Paul D. Merica; Horace W. Gillett — to name but a few, some sadly no more. There Bill Price was always to be seen. I like to think of him in those days, when this group, "Committee X", was assembled at the oaken board where the tankard was never dry nor the topic ever dull.

AULD LANG SYNE

By T. A. Hood
Defense Research Laboratories
Melbourne, Australia

Punch Card for the Field of Metal Finishing

AT THE Defense Research Laboratories of the Commonwealth of Australia's Department of Supply and Development, located at Maribyrnong, Melbourne (Victoria), a number of groups work in specialized fields, as follows:

Code	Field
0	Metal Finishing
1	Heat Treatment
2	Corrosion
3	Metallography and Constitution of Alloys
4	Powder Metallurgy
5	Chemical and Physical Analysis
6	Foundry Technology
7	Nondestructive Testing
8	Pyrometry
9	Welding and Joining

The men in each field of activity have been well aware of the great increase, during recent years, in the amount of technical and scientific literature being published, not alone in each specialty, but in various fields of knowledge more or less closely related thereto.

The mere existence of this mass of information is of little consequence unless specific data can be located readily. Abstracts published by the Institute of Metals and the Iron and Steel Institute (London), the American Society for Metals, and the American Chemical Society are invaluable, but they do not provide, and cannot be expected to provide, all requirements of the specialist. Many separate volumes must be consulted in the search for a complete bibliography on any one subject, the subject headings of existing indexes are not subdivided sufficiently, cross-references are inadequate and, since most of the references are not of interest to the user, any literature search is very tedious. Much valuable material, including Government reports and work by the individual's own associates (sometimes very extensive), is not covered in these indexes. Another inevitable difficulty with published abstracts is to locate *recent* references which have not yet been indexed. This lag between publication of a paper, its abstracting, and the publication of the index to the abstracts sometimes exceeds two years—although this criticism does not apply to the A.S.M.'s "Review of Metal Literature".

For these reasons, we at the Defense Research Laboratories have decided to keep separate (but coordinated) information files in each of our ten major fields of activity. This work has already been started by the group working on metal finishing problems, using an adaptation of the methods described by Guy and Geisler and by Westbrook and DeWald in recent issues of *Metal Progress* (December 1947, p. 993 and September 1948, p. 324, respectively). We believe that ten coordinated systems will result in better and more complete subdivision of subject headings than would be possible if the whole subject of "secondary metallurgy" were to be compressed into one system adaptable to a single design of punch card.

We are therefore hopeful that a brief description of our card for filing information about metal finishing will have a somewhat general appeal. We are aware that the American Society for Metals is sponsoring a study of punch-card filing methods; probably one result of such work will be a complete classification of the entire metallurgical field. However, our successful experience in a limited area may encourage others to institute personal filing systems utilizing this adaptable but simple equipment, and using the complete classification for matters outside their own specialty.

Preparation of Cards

While the mechanism of punch-card filing has been sufficiently described in *Metal Progress's* articles already quoted, the adjoining reproduction of our card will be helpful in explaining its preparation and use. Our card ("Paramount", 8x5 in.) is printed with triangular codes at right and left edges — a scheme that requires fewer holes and is easier to use than other indirect coding methods. Special meanings for special holes (as shown in the direct codes printed in the margins around the engraving) can also be printed on the card — as recommended by Westbrook and DeWald — but in the developmental stages we feel that the blank card is more suitable and quite adequate.

When the required information is typed or pasted on the card's face (and back, if necessary) the author's name is first coded. The first three letters are recorded in the three triangular codes on the right-hand side of the card. In each field the two holes are notched whose diagonal columns intersect at the letter to be coded. To code the upper letter in a given square, the left-hand position is notched with the shallow punch, and the right-hand position is notched with the deep punch. To code the *lower* letter, reverse the depths; in other words, the deep notch in the *left* position indicates the lower symbol. If there is more than one author, and it is desired to record them all, a separate card must be punched for each, and a cross-reference to the first author and the major subject section marked on it.*

Year of publication is next punched in the two triangular fields on the left of the card. Type of publication is directly coded at the bottom of the card (holes 1 to 6 inclusive). English language references are shallow-punched, and foreign language references deep-punched. If a copy of the original item is held, hole 66 on the lower right corner is notched.

Table I — Major Sections in Classification of Surface Finish

Code	Topic
0	Electroplating
1	Electropolishing
2	Electroforming
3	Metallic coatings (other than electroplate)
4	Nonmetallic coatings, organic (paints, lacquers, etc.)
5	Nonmetallic coatings, inorganic (coloring)
6	Nonmetallic coatings, electrolytic (anodizing)
7	Pretreatment, general
8	Cleaning, aqueous
9	Cleaning, electrolytic
10	Cleaning, mechanical
11	Cleaning, solvent

*Editor's Footnote — It appears that a disproportionate amount of space is given on this card to author's index, a matter ordinarily of minimum importance in a literature search. In other words, if a punch-card gets too crowded, the thing to compress or even leave off completely would probably be the author index.

Table II — General Subject Index

7. Bath Treatment
7. .....
8. General
9. Addition agents
10. Control
11. Filtering
12. Impurities
13. Maintenance
14. Fluid mechanics
15. Purification

8. Baths — by Composition
7. Cyanide
8. .....
9. Fluoborate
10. Trivalent chromium
11. Sulphate
12. Chloride
13. Fused salts
14. Pyrophosphate
15. Watts solution
16. Alkane sulphonic acid
17. Sulphamate

9. Equipment (Electrical)
7. General
8. Anodes
9. .....
10. Generators
11. Rectifiers
12. Control apparatus

10. Equipment (Nonelectrical)
7. General
8. Barrels
9. Racks
10. .....
11. Tanks and linings
12. Laboratory equipment
13. Floors
14. Corrosion resistant cements
15. Spray trapping device
16. Automatic

11. Theory
7. General
8. Chemistry
9. Current distribution
10. Distribution of deposits
11. .....
12. Polarization
13. Throwing power
14. Cathode potential

12. Miscellaneous
7. Economics
8. Health hazards
9. Mensuration
10. Reviews, history, research development, uses
11. Waste disposal
12. .....
13. Stopping-off
14. Stripping
15. Hydrogen embrittlement
16. Periodic reverse current
17. Heat treatment
18. Stopping-off for nitriding
19. Plating recessed areas
20. Heat treating
21. Etching
22. Influence of basis metal

Subject Index

The subject index is the most important part of the filing system. In order to select the most suitable subject headings a conventional card system and various published indexes covering the metal finishing field were analyzed. Subjects were divided into 12 major sections as listed in Table I, and these are coded in the third triangular field at the left of the card.† It was also decided that the subject headings under which references were most frequently looked for were as follows:

1. The metal being deposited.
2. The material or part being plated or otherwise treated.
3. Properties of the deposit.

All these items were directly subdivided and coded, as shown by the printing alongside the edges of the card at top and at bottom left, so that by two or three passes of a single needle a large file can be rapidly and progressively reduced to a small number of cards.

The preparation of this card, therefore, required the following steps:

1. Major section ("Electroplating", Section 0 in Table I) is noted by notching for 0 in triangular code on left edge of card.

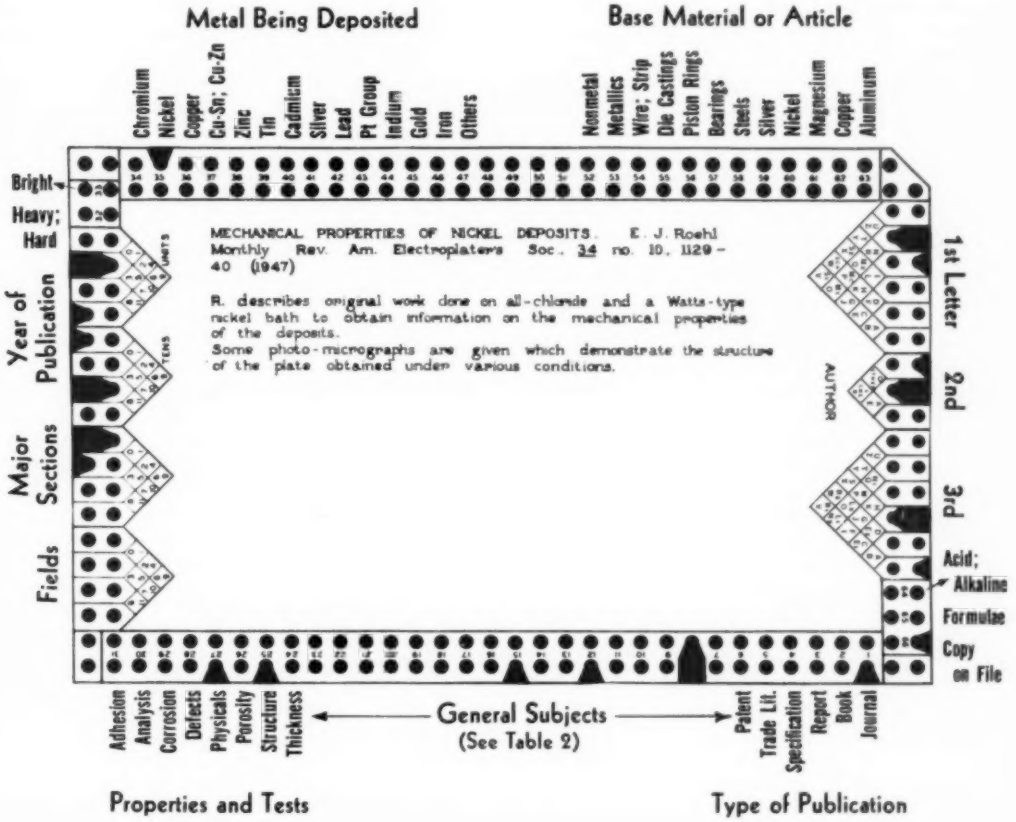
2. Metal being deposited is direct coded. "Nickel" is indexed by notching 35 on top edge. Notch shallow for pure metal, deep for alloy (34 to 47). Notch "bright", "heavy" or "hard" (32 and 33) where applicable.

3. Index metal or part being treated by notching direct code for holes No. 52 to 63 at upper right. (No punching in this region is required in this instance.)

4. Index properties (shallow notches) and testing methods (deep notches) on the direct code at bottom edge (No. 24 to 31). This article is coded as containing information on physical properties and microstructures.

Next comes the general subject index. Holes 7 to 23 are available along the bottom edge, and these are used for indirect coding according to Table II. For the particular article shown in the engraving, deep punch 8 refers to Subject Heading

†Major fields of our activities, as listed at the outset of this article, are punched in the bottom triangle; for the time being, all cards constructed by the Metal Finishing Group are retained in a single file, and a punching for Field 0 is unnecessary.



8—"Baths, by Composition". Shallow punches 12 and 15 refer to corresponding items under Heading 8 in Table II, namely, "Chloride" and "Watts solution". Although more than one principal subject heading (deep) may be notched on a card, this practice may result in unwanted cards falling, and to avoid this only one principal subject is ordinarily notched on each card.

Extracting Information From File

Cards can be selected from the file by proceeding as follows:

1. On a given subject:

(a) Decide major section (or file).

(b) Needle appropriate holes in direct code (or codes).

(c) Needle deep hole for principal heading, and then shallow hole (or holes) for subheading in general subject index.

2. Selecting particular types of publications:

Needle the appropriate shallow hole in the direct code. To separate foreign language references pass needle through the deep hole, whereupon foreign language references will fall and references in English will remain on the needle.

For example, to select cards on "mechanical properties of nickel deposited from a Watts-type nickel bath":

(a) Decide on major section file to be used—in this case pass needles through holes for "No. 0, Electroplating". Discard cards that remain on needle.

(b) Pass needle through No. 35, shallow. (All cards dealing with *nickel deposits* will fall; discard all others.)

(c) Pass needle through hole No. 27, shallow. (All cards dealing with *physical properties* of nickel deposits will fall; discard all others.)

(d) Pass one needle through hole No. 8, deep, and another through No. 15, shallow. (All cards dealing with physical properties of nickel deposited from *Watts-type baths* will fall.) These are the ones sought.

3. To select writings of a given author:

First letter. Upper triangular code. Take diagonals from required letter. If letter is upper one in square, needle shallow hole on left diagonal, and deep hole on right diagonal. If the required letter is the lower one in the square, needle the deep hole on the left diagonal and the shallow hole on the right diagonal.

Second and third letters are selected from the adjacent triangular codes in the same way. This may be done with one needle, but the use of two needles simultaneously is quicker.

Correspondence

Specifications for Structural Steel in Low-Temperature Service

PORT WASHINGTON, N. Y.

To the Readers of METAL PROGRESS:

For some time numerous research departments in industry and universities have been conducting extensive tests to determine the notch sensitivity of steels used for ships. Reasonably good correlation has been established between small specimens and full-scale tests of notched plate, and a comparison of the various types of specimens has been published. However, numerous laboratories continue to evolve new types of specimens and tests which seem to add little in the way of new information and perhaps tend to confuse the knowledge gained.

I strongly believe that far greater benefits and progress could be achieved if efforts were now made toward correcting current specifications in such a way that requirements would yield reasonable assurance that the steel supplied would be free from notch sensitivity. This could only be achieved through concerted action on the part of all metallurgists involved.

One of the first corrective measures has been taken by the American Bureau of Ships in its specifications for ship steel, through chemical requirements that assure a beneficial ratio of manganese to carbon and a grain-refinement heat treatment for heavy plates. Although the requirements have been questioned, they are certainly a step in the right direction.

Unfortunately, many other specifications, such as those for plate for pressure vessels, structural steel and other equipment, contain no requirements which insure that material free from notch sensitivity will be furnished, except for materials specifically ordered with special low-temperature properties.

The definition of what constitutes low-tem-

perature service is somewhat abitrary and controversial, and will necessarily remain so because past experiences are numerous where materials have behaved satisfactorily at low temperatures. In spite of past experiences, I believe that all specifications should be currently reviewed in the light of present data to insure that materials of the highest attainable properties will be furnished for all important services.

ALBERT W. ZEUTHEN

Britain's Combat With Corrosion

LONDON, ENGLAND

To the Readers of METAL PROGRESS:

Studies on corrosion and its prevention were greatly stimulated during the war, for it was found early in the campaigns in Burma and New Guinea that about 10% of the materiel was destroyed by corrosion before it reached the soldier. W. H. J. Vernon, head of the corrosion section of Britain's Chemical Research Laboratory, estimates that about 50 years' work at normal tempo was telescoped into five. A large proportion of this work concentrated on marine corrosion—an important question for Britain's shipbuilders, who produce more than half the world's ships. The various metals used in ship construction deteriorate not only because of the saline character of sea water but also from erosion caused by the constant swirling action of the water. The Corrosion Research Station developed a "high-speed rotor device" to determine quickly the corrosion resistance of different metals and protective coatings in sea water and fresh water.

Like many of the best inventions, it was an extremely simple device, consisting of a round ebonite disk, in which could be fitted six small specimens, and which was driven by a $\frac{1}{2}$-hp. electric motor at speeds up to 1500 r.p.m., corresponding to a peripheral speed of about 20 knots.

Simultaneously with these rotor tests, large steel plates with the same protective coatings as were being tested with the rotor device were suspended from a raft in Plymouth Sound, off the southern coast of England, and their rate of decay noted. Britain's Admiralty also cooperated by painting special panels of some of its ships with selected paints to investigate their behavior under service conditions. At the conclusion of these initial tests, it was found possible to relate the short-term tests using the motor device to the results of testing by normal conditions of exposure. A laboratory test of only 50 days with the rotor apparatus was found to be equivalent to about 12 months at sea. The immediate result of these findings was that unsatisfactory coatings could often be rejected after as short a period as one day's test. Eighteen of these rotor units were in continual use day and night during the war and by this means valuable knowledge about the performance of ships' antifouling paints increased rapidly. When the tests began, it was rare for a normal ship's paint to withstand 50 days of testing, whereas after the tests had been developed and proved, compositions were found that would last more than three times as long. This centralized testing technique operated within the framework of Britain's Department of Scientific and Industrial Research. This department cooperated with private manufacturers of proprietary protective coatings, who learned from the results of the tests how to improve the quality of their product.

Corrosion caused by antifreeze solutions used as substitutes for ethylene glycol or glycerine in the cooling systems of the internal combustion engine presented another problem, for the liquids selected had to be without corrosive action on any of the metals used in the construction of the cooling system. A number of different solutions were tried. For example, sodium lactate solutions showed relatively slight corrosion in contact with iron and steel but had an intense attack on aluminum and aluminum alloys.

Next, therefore, it was necessary to find corrosion-inhibiting agents that would prevent the corrosion of sodium lactate and aluminum. These were found and examples of them were sodium fluoride and sodium arsenite. Even then, however, the problem was not solved because the commercially available sodium lactate contained impurities which effectively prevented these inhibitors from acting efficiently—and after this lengthy investigation had gone so far, it had to be abandoned. We are accustomed to reading of effective discoveries, but slight publicity is given the many investigations, of which this is an example, where success is elusive.

However, another material was investigated—sodium benzoate. It was quite a good anti-refrigerant and in the concentrations used it was virtually noncorrosive toward the metals normally employed in radiator systems—even under the drastic conditions of intermittent heating and cooling. Again, laboratory tests were related to experience and the Wheeled Vehicle Experimental Establishment at Farnborough, England, carried out a large number of road tests using the cooling system of Bedford trucks.

Having discovered the corrosion-inhibiting characteristics of sodium benzoate, consideration was next given to its use in hard water or distilled

water to prevent the corrosion of iron, aluminum and other metals under conditions of intermittent heating and cooling. It was found to be very effective. About 1.5% of sodium benzoate in an ethylene glycol or a glycerine antirefrigerant imparted corrosion resistance to mild steel that was soldered to brass. In addition it prevented the choking of radiators by scale built up on the walls of such heating systems.

The packaging of goods destined for the tropics had also taxed the ingenuity of Britain's service departments for quite a while. Certain wrapping materials were found to encourage corrosion. Because sodium benzoate had remarkable rust-inhibiting properties, it was used to impregnate wrapping papers. Results showed that steel specimens wrapped in dried paper that had been dipped in a 5% solution of sodium benzoate and water remained quite bright after exposure in warm humid atmospheres of the tropics. This is another example of a specific war investigation that is now finding industrial application in the packing of goods for export.

Another problem was the corrosion of metals confined in packages or containers in which the air is sealed. A material was needed that vaporized and would also have the effect of preventing corrosion. Since sodium benzoate had been effective in radiator systems, vaporizing materials resembling it in chemical constitution were examined. Of them butyl benzoate was found to be extremely effective and the amount required was just enough to saturate the air space.

Soil pipes are another corrosion problem. The United States estimates its loss from the corrosion of buried pipe lines at $120,000,000 per year. One paradox is that failures occur quite often in clay soils where atmospheric oxygen is more or less excluded from contact with the buried metal. It had been thought previously that access of oxygen was an essential controlling factor in the corrosion of pipe lines. However, the Chemical Research Laboratory investigated bacteria abundantly present in clay soils. These organisms are able to react with the metal sulphates present in the clay in contact with iron, so helping the oxygen in the sulphate to play its part in the pipe corrosion. Cast-iron pipes buried in clay often become so soft in parts that they can be cut with a knife or scratched with the finger-nail. In practice, the pipes become useless and burst long before the process has gone as far as this. Failure can occur in as short a time as 12 months. With this discovery an entirely new corrosion problem, previously unexpected, was opened up and the Chemical Research Laboratory, cooperating with London's Metropolitan Water Board, is investigating the effects of this bacteria corrosion with a number of experimental stretches of water mains.

These researches by a department not primarily interested in manufacture and production preserve a strict impartiality. In turn, the manufacturer has the benefits of this fundamental research carried out in Government departments. This cooperation between the private enterprise of commerce and the Government departments acting for the specific purpose of supplying industry with the results of fundamental research is improving the quality of Britain's manufactures. It is characteristic of the relationship of the Department of Scientific and Industrial Research and private enterprise that today, in Britain, manufacturers are quick to seize upon a favorable comment from an impartial Government investigating department and to use these tests as the best means of advertising their products.

WILFRED F. COXON
(formerly Principal Technical Officer,
Britain's Ministry of Aircraft Production)

Stainless Steel in Bridge Bearings

HARRISBURG, PA.

To the Readers of METAL PROGRESS:

When the bridge or structural engineer needs to use a metal with a higher yield strength than ordinary carbon steel of structural grade, he turns to what is known as "structural silicon steel", whose alloy content is so low that mechanical engineers would hardly class it as an alloy steel at all. Nevertheless, for one important item we have had to go all the way to the 18-8 chromium-nickel stainless steels!

Some 10 or 12 years back we found that many of the existing large bridge structures were being destroyed or their usefulness curtailed by the fact that the expansion bearings (made of ordinary carbon steel) became corroded, locked up, and the structure did not properly function as designed. We introduced the use of stainless steel or bronze in all the important expansion bearings, thus stopping, we hope, the corrosion of these important features in truss bridges.

I believe the first use of stainless steel in bearings of this type was in the continuous girder span bridge over the Potomac River in Washington, D. C., known as the Chain Bridge, built about 1937. These bearings have been periodically inspected and are still in perfect condition.

FRANK M. MASTERS
Modjeski and Masters
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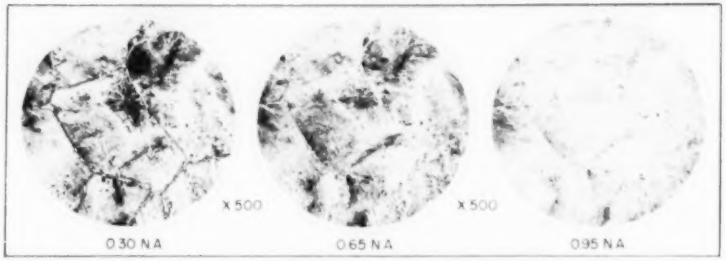
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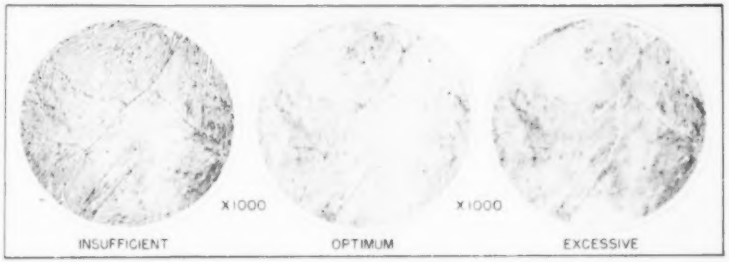
Metallographic Technique for Steel: Photomicrography

*Sheet III of Six Prepared by Research Laboratory, U. S. Steel Corp.**

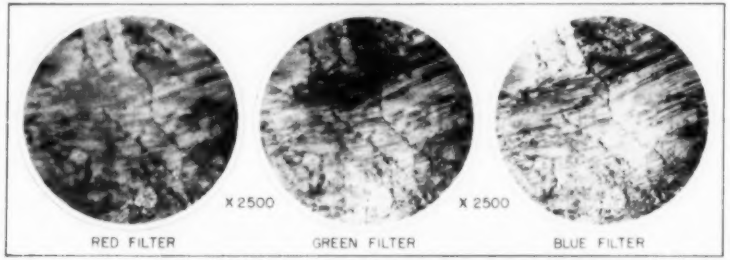
NUMERICAL APERTURE & RESOLUTION



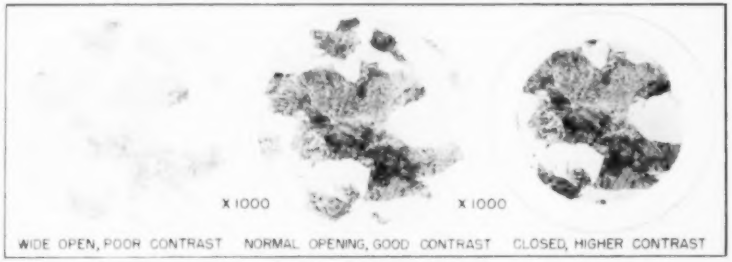
IRIS OPENING & RESOLUTION



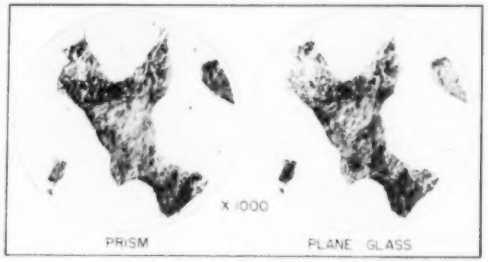
WAVE LENGTH & RESOLUTION



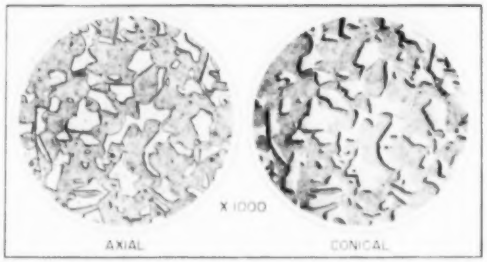
OPENING OF FIELD DIAPHRAGM & CONTRAST



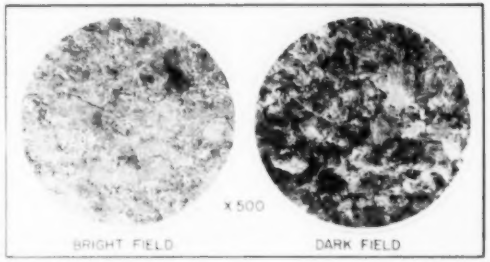
PRISM & PLANE GLASS ILLUMINATORS



AXIAL & CONICAL ILLUMINATION

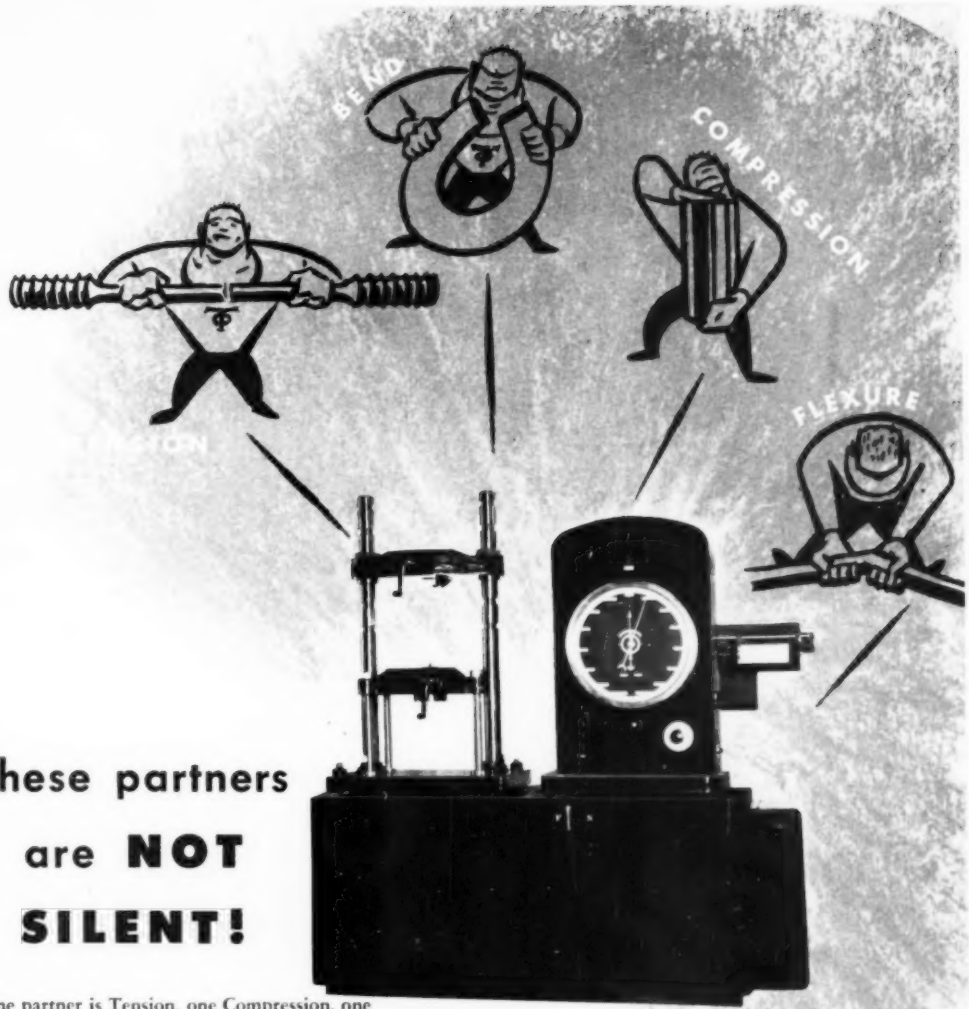


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See also "Metallographic Technique for Steel", by J. R. Vilella, published by The American Society for Metals



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Metal Progress; Page 80-D

By George A. Nelson
Shell Development Co.
San Francisco

The Probolog, for Inspecting Nonmagnetic Tubing

TUBULAR equipment for heat exchangers, condensers, and coolers is widely used in oil refineries, chemical plants, steam power plants afloat and ashore, sugar mills, and all sorts of processing. A piece of such equipment consists of hundreds or even thousands of parallel tubes (usually of brass or some special alloy of copper) arranged in bundles inside a metal container or shell. The petroleum industry alone has literally thousands of heat exchangers and condensers in constant operation. Through the tubes pass all crude oils en route to refining; in these exchangers they are heated by an exchange from hot outgoing gases or liquids on the outside of the tubes. Condensation of gasoline from a vapor to usable liquid is performed in condensers. Here the outgoing gases pass around many tubes which are cooled on the inside by constantly flowing water. Steam power plants have condensers containing as many as 20,000 tubes through which cold water flows to condense low pressure exhaust steam. Ships also have condensers in their boiler installations.

Inspection of these tubular elements for interior or exterior deterioration has been a difficult problem. When a small oil refinery condenser is withdrawn from service the general condition of the outer ring of tubes may be observed from the outside. Because of their close packing, the inner tubes cannot be seen. Also, the *inside* of the tubes can be examined for a few inches from the ends; beyond that point, inner surfaces of tubes are difficult, if not impossible, to inspect. In large fixed condensers, such as are used in power plants and on board ships, outside inspection is impossible, and tubes can be visually inspected from the ends only. Under such circumstances several tubes would be withdrawn, split, and visually examined on the inner and outer walls for a rough guide as to the condition of the others. This method of testing yields some valuable information but does not give any direct data on the tubes remaining in the element, some of which may be near the point of failure.

Being faced with a need for a device which would yield data upon which the inspection engineer could more accurately predict the service life of tubular elements, Shell Development Co. has produced an instrument which indicates and records any defective areas in nonmagnetic tubes. This instrument, known as the "Probolog", has now been in successful use for the past several years, and it is the purpose of this article to enumerate several advantages to be gained by its use.

The Probolog is an instrument that detects and indicates or records all types of irregularities in tubes of nonmagnetic metals such as the brasses and austenitic steels that are found in heat exchangers. In particular, it reveals the presence of defects such as large or small holes, cracks, internal or external corrosion, erosion pits, recrystallization, nonuniformity of wall thickness, and dezincified areas. The instrument graphically presents all of this important information to the maintenance and inspection groups charged with the responsibility of deciding whether to replace a costly exchanger bundle or take a chance on having an unscheduled shutdown.

The instrument is portable and can be operated by one man. Tubes are inspected from the inside and therefore no special preparation of the tubular equipment is required before inspection other than opening up the front end, laying bare the tube sheet. The tubes do not even need to

be cleaned if they are open enough to pass the sensing element or probe.

Figure 1 shows the Probolog components:

1. One or more interchangeable probes of diameters to fit standard sizes of tubing.
2. A mechanical probe puller, essentially a motor-driven roller synchronized with the chart drive of the recorder, and a friction element that grips the connecting wire. This insures a precise correlation between chart recording and probe position in the tube being inspected.
3. An electronic recorder, equipped with a continuous strip chart.
4. An accessory recently added is an air gun (right foreground of Fig. 1) which aids in projecting the probe to the far end of a tube; it saves considerable time and wear on the connecting cord.

In its operation, the functions of the electrical components might be described as follows:

When the probe is placed in nonmagnetic tubing it generates a magnetic field by electric current flowing through a pair of coils it contains. This field penetrates the walls of the tube and induces eddy currents which, in turn, exert a reciprocal influence on the coils within the probe, and modify their electrical impedance. When the probe is pulled through a *normal* piece of tubing, all the electrical characteristics are in balance, and this normality can be indicated by an electronic recorder and charted on a strip of paper as a straight line. When the material in the tube is *abnormal*, such as might be created by corroded walls, the eddy currents are distorted and such distortions are recorded on a strip chart as deviations from a straight line.

Preparation of this equipment for inspection consists merely of connecting to any handy lighting circuit and plugging the probe-puller and probe into the recorder unit. (If the air gun is to be used, a connection to a 110-lb. air line or a cylinder of compressed air is necessary.) Desired sensitivity setting is selected, and the instrument is balanced by placing the probe in a defect-free portion of tubing and adjusting the recorder so the pen is at the center line of the strip chart. The probe is then pushed through to the far end of the tube, the probe cord is placed between the knurled wheels, the probe-puller is started, and the probe is pulled out of the tube at a uniform rate (usually 12 ft. per min.). The chart drive simultaneously unreels at a rate of 12 in. per min. Figure 2 shows the Probolog in operation at the head of a refinery condenser.

Since chart and probe move at a proportionate rate, the record drawn by the pen locates the position of any defect in any part of the tube, and its relative magnitude. The instrument will also show, to a fair degree of accuracy, any uniform loss or gain in wall thickness by an offset of the average position of the pen from the center line. The chart record can be calibrated in terms of wall thickness with an accuracy of ±5%. This accuracy is impaired, however, by corrosion conditions that introduce tube eccentricity or tapered walls.

Advantages and Limitations

The limitations of the Probolog relate mainly to the variety of metals that can be inspected and the interpretation of the chart. The present instrument is designed specifically for nonmagnetic tubes, including such metals as copper, brass, Inconel, admiralty metal, copper-nickel, muntz metal, aluminum, and austenitic stainless steels. These comprise the great majority of alloys used for condensers or heat interchangers.

Indications of the record are not positive in that an inspected tube is not labeled as "good" or "bad". Whether a tube should be retained or discarded is a matter of proper interpretation with respect to standards established in the field. These standards can be instituted by splitting representative tubes which have been probed, and comparing the actual conditions with the corresponding pen deflections on the strip chart. The number and



Fig. 1 — Probolog Inspection Unit; in Foreground, From Left to Right, Are Probe, Two Connecting Cords, and Air Gun. In the background are carrying case, probe-puller and recorder. Other accessories such as test plug, paper, ink and standard tube are in front of the probe-puller

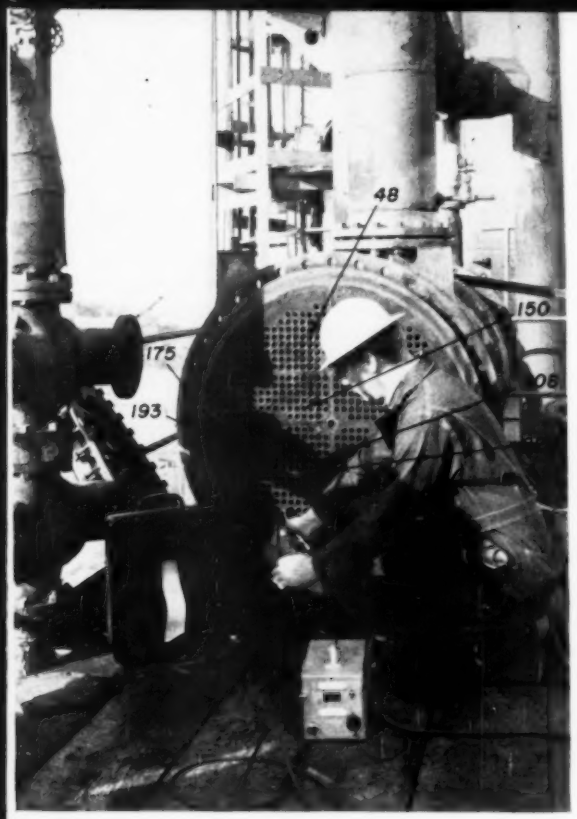


Fig. 2 — Probolog Inspection Unit in Operation at Head of an Oil Refinery Condenser. Operator is about to shoot probe into tube with air gun. Records made from tubes located by numbers are shown in Fig. 3

magnitude of pen deflections are then related to the severity of corrosion. In the same way, general corrosion (uniform thinning of tube walls) can be related to offset of trace from center of strip chart.

When the information is properly evaluated, many savings have resulted. A few instances will now be cited.

Numerous tube bundles have been inspected and the records revealed that corrosion has been selective, being more prevalent in one part of the bundle or of the entire condenser than in another. Sometimes only a portion of such a bundle has been replaced; in other instances the bundle has been rotated through 180° and the life of the remaining tubes prolonged.

Since using the Probolog it has been found that the rate of corrosion may vary considerably with the location of the tube in the bundle. This suggests an improvement in condenser design, either as to flow of liquid or selection of proper metals to be used in different parts of the same bundle.

For example, Fig. 2 was taken in one of our plants where experiments have been under way for the past three years to select the proper tube material for a particular unit. Tube materials under test consisted of the following metals: steel, aluminum, inhibited admiralty metal, muntz metal, inhibited muntz metal, and bimetallic tubes (inhibited admiralty inside and aluminum outside in one type and inhibited muntz metal outside in the second type). Treated well water at 70 to 80° F. was passing through the tubes; surrounding them was a steam-heated solution of phosphate containing some H_2S at 150 to 170° F. Tubes were ¾ in. outside diameter, 16-gage wall. Representative portions of the charts from the tubes located in Fig. 2 are shown in Fig. 3. Service was 30 months. It was found that the corrosion was limited to the inner or water side, and that steel

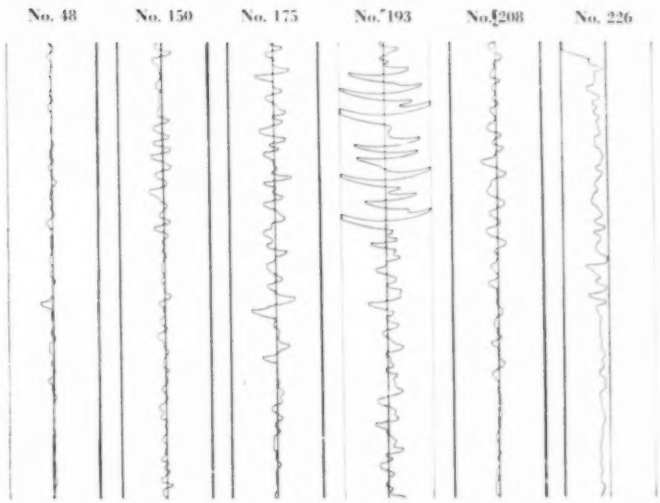


Fig. 3 — Records of Tubes After 30 Months in Experimental Tube Bundle, Exposed Inside to Treated Well Water at 75° F. and Outside to Hot Water (160° F.) Containing H_2S and Phosphate. Nature of tubes:

No. 48 — Inhibited admiralty metal
No. 150 — Muntz metal
No. 175 — Inhibited muntz metal
No. 193 — Muntz metal
No. 208 — Duplex tube
No. 226 — Aluminum brass

and aluminum tubes had failed. A careful Probolog inspection was made of remaining tubes in order to select the best type of metal for replacement. The charts show several things clearly:

1. Corrosion and dezincification of the tubes was much less severe on the top (cold) side than on the bottom (hot) side. Compare muntz metal tube 150 with tube 193.

2. Inhibitors added to muntz metal have a definite tendency to reduce damage to metal by dezincification. Compare tubes 175 and 193, both from the hot or worst side of the element.

3. Inhibited admiralty was generally good on both hot and cold sides and compared very favorably with aluminum brass. Compare tubes 48, 208, and 226.

As a result of the information from this inspection, all tubes except inhibited admiralty and aluminum brass were removed from the bundle and replaced with inhibited admiralty metal.

Localized Corrosion

Figure 4 illustrates the effects of localized corrosion in portions of tubing. The chart at the left represents the condition of tubes on the hot side of a bundle and shows only minor deflections, whereas a tube from the cold side in the same bundle is badly corroded near the tube sheet, as shown by the center chart. The corrosion was found on the outside of the tube and was caused by a condensation of a corrosive near the coldest part of the element. Tubes having this type of pattern are removed from the bundle, the bad area cut off, and the remaining good portion reused in shorter bundles. These two charts also demonstrate the accuracy of the Probolog in locating metal disturbances on the *outside* of the tubes, such as the baffles which, in effect, represent an increase in metal thickness. The instrument, in fact, is occasionally used for an accurate log of the distance between baffles.

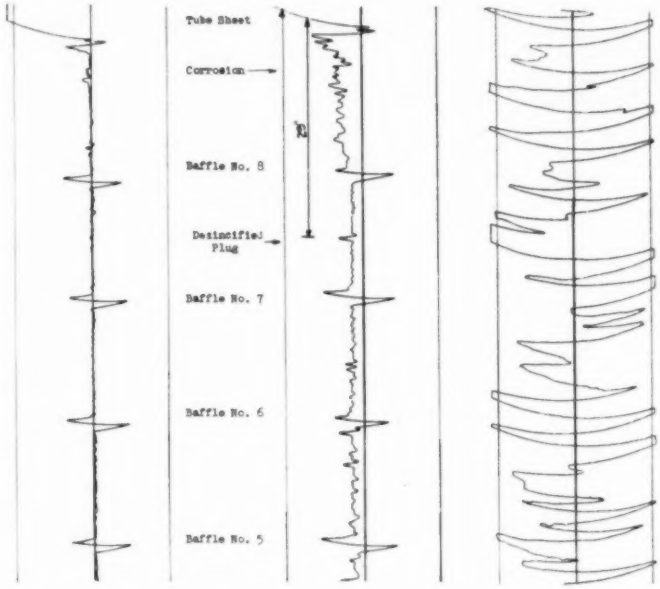


Fig. 4 — Records of Corrosion Encountered in Muntz Metal Condenser Tubes After 18 Months in Steam Condenser. Left — sound tube from hot side. Center — tube from cold side corroded on outer surface near tube sheet. Right — severe dezincification (chart running at three times speed of others)

The pattern shown in the third chart of Fig. 4 indicates severe dezincification on tubing from another bundle. This tube was muntz metal and had operated in a steam condenser for about 18 months.

Optimum Use — Having an instrument of this type at hand, the question of using it to its best advantage continually arises. The technique varies with the particular type of operation or location of the tubular element.

On examining a bundle in an oil refinery during a shutdown, when only a short time is available, Probolog records are usually made in a criss-cross pattern. Starting at the first tube in the upper left-hand zone, one tube in each row is logged, continuing down to the lower right-hand zone. Starting again at the upper right, the inspecting proceeds to the lower left with one tube in each row. This method permits a rapid evaluation of questionable zones, which can then be further explored by logging a number of tubes surrounding any showing wide pen deflections. One or more of these bad tubes can sometimes be withdrawn from the bundle for comparison with the record charts and a decision reached as to the necessity for withdrawing the entire bundle or as to leaving it in place for another run.

On the other hand, when a bundle is known to have been leaking, the Probolog is used as a supplement to the hydrostatic test. By this

method, water is forced under pressure around the tubes while they are still in the shell, and leaky tubes are immediately located. If a large number are leaking and they are scattered over the cross section, it can be concluded that the entire bundle is in bad condition. When there are only one or two leaky tubes, the Probolog can be used to good advantage. After making a record of the leaky tubes, they are withdrawn, split, and defects checked against the record. Subsequently, the remaining tubes in the bundle are logged, and those near the point of failure are located. Such failures have been isolated in only one pass of the bundle, where necessary repairs were made. It has also been found that a single failure had been caused by the installation of a tramp tube entirely unsuitable for the service. The Probolog showed that all the adjacent tubes were in good condition; therefore, the bundle was retained in service after the defective tube had been plugged.

A probe that sets up and measures eddy currents in the walls can indicate irregularities in thickness of brass tubing due principally to corrosion or dezincification, and can thus spot defectives or tubes about to fail. Hitherto about all that could be seen in a tube bundle — except by completely dismantling — was a few inches of the insides at either end. The instrument can also be used to explore the condition of tubes prior to re-use, and to separate mixed lots by composition.

For the inspection of large surface condensers, such as are used in power stations, a somewhat different procedure is required. Here we find elements containing many thousands of tubes. The covers are sometimes 3 ft. from the tube sheet, and have entrance manholes. Upon inspecting one of these condensers, all tubes directly back of the manholes are Probologged. For checking tubes not directly in back of the manhole, one operator gets between cover and tube sheet, projects the probe to the far end of a particular tube, and at a proper signal to another operator on the outside, the puller and recorder are started simultaneously.

Another phase of Probolog recording is that used by refineries, particularly in the Arabian area where replacement tubing is difficult to obtain and very expensive. In these areas, every tube that has been withdrawn from condensers is surveyed by the instrument to determine if there is sufficient sound metal remaining to use in a shorter element.

Sorting of mixed tubes may also occasionally be done. Due to the electrical property differences, many types of condenser tube alloys can be separated by balancing the pen to a center line in a tube of known analysis. Then by inserting the probe into the unknown tubes of the same diameter and wall gage, all tubes with the same analysis as the standard sample will cause the pen to stop at the same center line. In order to identify the other tubes, corresponding standards from other known materials are first established.

By the proper use of this instrument, considerable saving in material and improvement in plant performance can result.

Savings Realized

In its first year period of operation at one of our refineries, the Probolog was used to inspect 16 tube bundles. From these bundles, approximately 2750 copper alloy tubes were recovered, costing about $3900. Actually, the saving was somewhat less if the cost of inspection and reconditioning tubes is included. On a basis of a labor cost of $0.233 per tube the actual saving was about $3600. The labor cost includes the following: labor cost for inspection, 5.5¢ per tube; cost to remove tube, 17¢ per tube; cost for trimming ends, 0.8¢ per tube. These labor costs are based on large bundles, and will vary according to bundle size and tube conditions.

At another refinery, savings of approximately $4000 were realized in a study of a large surface condenser at the catalytic cracking plant and a large condenser at the topping plant. The staff expects savings to accrue of from $10,000 to $15,000 per year.

The two examples just described illustrate quite well what might be called the cash savings. However, there is no way of showing how much has been saved from better operation, prevention of forced shutdowns, or prevention of accidents to personnel. Such intangibles are ever-present and if they can be minimized, savings would result far in excess of tube replacements.

By Helmut Thielsch
Research Engineer
Lukens Steel Co.
Coatesville, Pa.

Bulge Testing of Sheet Metal

IN RECENT YEARS considerable progress has been made in the understanding of bi-axial and tri-axial states of stress, and many investigators have begun to explore systematically the different criteria associated with the various types of failures found in simple and complex structures. Among these the more fundamental are concerned with studies on the bulging and rupture of sheet specimens clamped in circular flanges. In such testing, the principal stress perpendicular to the plane of the sheet is assumed to equal zero, and the other two lying in the plane are equal in magnitude. Thus there is a condition of bi-axial stress in the sheet.

Most of these investigations have been concerned with *theoretical* aspects pertaining to the plastic flow and rupture of sheet metals.[1] Some authors have suggested that the quantitative data derived from bulge testing may be related to the formability of the sheet metal tested. However, this method is just as important as a standard testing technique.

The bursting of sheet specimens in the circular bulge represents a test of considerable sensitiveness — far more, for example, than can be obtained with the conventional tensile test on sheet specimens. This sensitiveness[2] has found an important application in the manufacture of frangible rupture diaphragms by Black, Sivalls & Bryson. These are used commercially as a protecting device for pressure tanks and vessels. Bulge testing could therefore become very useful in determining the quality of sheet metal products.

The essential features of this testing equipment are shown schematically in Fig. 1. The sheet specimen simply is clamped between two flat flange plates. In units having an inside diameter below 2½ in. the edge of the upper clamp ring should be rounded somewhat; otherwise shear fractures may occur at the edges.

Pressure is applied from one side, either from an air compressor or hydraulically. The latter method is of greater convenience since the pressure line may be attached to the oil system of a standard tensile testing machine. As pressure is applied the sheet specimen will begin to bulge out at its center, forming a segment of an approximate sphere.

The pressure at which the bulging specimen will rupture or burst is inversely proportional to the inside diameter of the flange. This relation is shown in Fig. 2 for aluminum sheet specimens of types 2S-O and 75S-O. These curves were obtained from experiments with test flanges of different inside diameters. As Bonyun[3] pointed out, this relation can be expressed by the function

$$D = \frac{k}{B}$$

where D is the diameter of the diaphragm (that is, the inside diameter of the upper clamp ring), k is a constant which, for a specific specimen thickness, will be characteristic for the material, and B represents the pressure necessary to "burst" the sheet specimen (that is, the bursting pressure). The equation is that of a hyperbola having its asymptotes as the coordinate axes, and plotted as straight lines on double logarithmic paper.

In using the equipment of Fig. 1, normal tightening does not produce edge effects. Only in extreme cases was a slight increase noted in the bursting pressure of sheet specimens clamped in flanges having diameters of less than 1½ in.

So much for a single material, such as fully annealed aluminum. To obtain a fundamental relationship between the bursting properties of

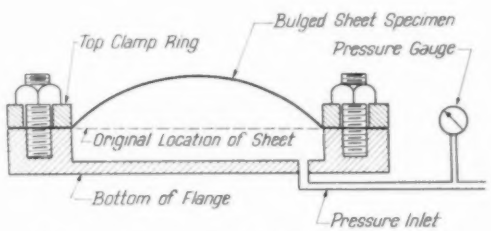


Fig. 1 — Arrangement of Bulge Testing Equipment

different materials a new standard term, the "Unit Bursting Factor" (Ubf), has to be derived. This factor, of course, will be relative, and is defined as the theoretical pressure necessary to rupture a material 0.001 in. thick in a flange having an inside diameter of 1 in. Thus

$$\text{Ubf} = \frac{B \times d}{t}$$

where B is the bursting pressure at any diameter d of a specimen t thousandths of an inch thick.

To each roll or sheet of material can be assigned now its Ubf, or, since the thickness of a rolled sheet product should be constant, it could be classified also by a *Bursting Index* (B_1), obtained by multiplying the Ubf by the thickness t of the sheet. Then the bursting pressure B at any diameter can be found by dividing B_1 by d, the flange diameter.

Formability of sheet metal was given intensive study during the war. One of the tests for determining bi-axial strength is the "bulge test", and this has received much theoretical study. This brief article attempts to bridge the gap over into the realm of testing materials, the author believing that results of a bulge test may readily have a better correlation with the formability of sheet metals than the other cupping tests that are frequently used with indifferent success.

Determinations for the Ubf of 2S-O aluminum were made on several hundred different rolls. Plotting the results against the individual thickness of the respective sheet will give a curve somewhat similar to a familiar stress-strain curve. Above a thickness of about 0.020 in. the curve flattens out to assume a constant value, being 45.5 lb. This, then, is the *characteristic* Ubf for 2S-O aluminum sheet. The rather rapid drop of the Ubf for thinner gages is probably due to surface defects in the very thin specimens. In the 2S-O aluminum, 98% of the sheets tested varied less than 5% from the curve of the *median* Ubf. Actually the *median* curve corresponds closely to a *mean* of the experimental values. Upon careful examination the other 2%, which fell below this range, showed surface irregularities such as streaks of porosity, or scratches. Standard tensile tests did not reveal the influence of such imperfections.

In comparison to tensile tests, bulge testing gives results of far greater reproducibility. This becomes evident from the results such as a series of tests on a sheet of 2S-O aluminum, 0.0252 in. thick, ruptured in a flange having a diameter of 5 in. Companion tensile specimens were stamped out in a die, and were polished at their edges to remove die markings. As only the *scatter* of actual test data is of interest here, the tensile results (pounds) have not been converted to unit stresses. Bursting pressures in the bulge test (psi.) were 231, 234, 232, 232, 230, 232, 233, 232, 233, 231; the maximum deviation from median was 0.86%. The loads on tensile specimen in the tension test (lb.) were 174, 186, 193, 194, 189, 179, 190, 177, 183, 188; the maximum deviation from median was 5.4%.

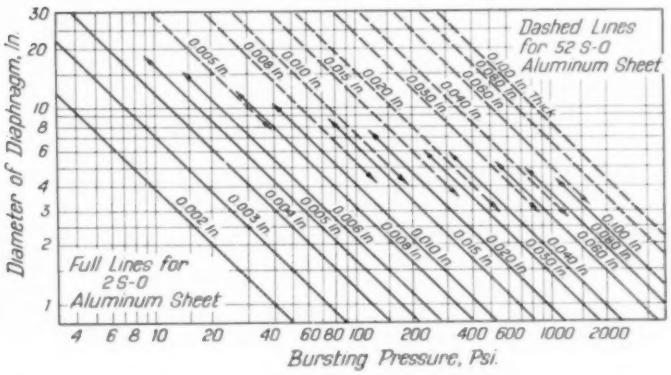


Fig. 2 — Bursting Strength Versus Diaphragm Diameter for 2S-O and 52S-O Sheets of Various Thicknesses. Slopes of all lines are parallel

Enough work has been done on four aluminum alloys to locate curves of Ubf versus thickness. Each one levels off to a constant value above a certain thickness, thus:

Alloy	Characteristic Ubf	Thickness
2S-O	45.5 lb.	0.020 in.
3S-O	50	0.020
52S-O	83	0.025
24S-O	92	0.030

In some of these the deviation or scatter from the median is more pronounced. This is due to the additional structural

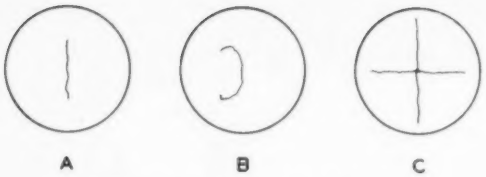


Fig. 3 — Ductile Failures in Bulge Tests

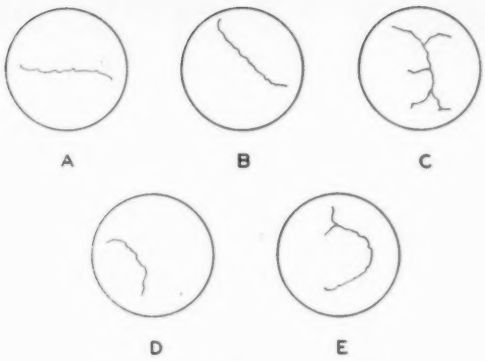


Fig. 4 — Brittle Failures in Bulge Tests

phases which appear in these alloys: obviously, the constituents representing additional phases will have their own physical properties such as ductility and strength. Moreover, the deviation will be larger in thinner sheets, below 0.020 in.

Results of greatest uniformity are obtained for sheets or plates in their soft annealed state. Rupture in the bulge is a function of the ductility and the strength of the material. Since cold working a sheet will lower its ductility, the ability of the sheet to stretch or bulge out will be reduced, consequently lowering the over-all bursting strength. For example, 2S aluminum, "one-quarter hard", will rupture at a pressure 3 to 6% lower than the same material would in its soft annealed condition.

Elevated temperatures, on the other hand, though increasing somewhat the sheet's ductility, will lower the strength of the cubic metals more severely. This is shown by the following values for the tensile strength and the bi-axial rupture strength of 2S-O aluminum.

	Bursting Pressure	Tensile Strength
70° F.	100% (datum)	100% (datum)
150	89	93
250	73	80
350	52	63
450	35	44

Sachs, Espey and Kasik[4] give similar graphs for the major aluminum alloy sheet materials. Moreover, the same authors have shown that the type of fracture also will provide an indication of the condition of the sheet. Thus, in hydraulic rupture tests, normal ductile failures of structurally homogeneous materials are evidenced by a straight crack, as in Fig. 3A, running in the rolling direction. The crack will originate in the immediate center area of the top crown. In addition to this type some ductile (soft annealed) alloy sheets may fracture in a C-shaped flap-like fashion, Fig. 3B, again originating in the center area of the crown. Normal ductile rupture diaphragms burst by compressed air will exhibit an orange-peel type of fracture, like Fig. 3C.

Brittle failures in hard or defective materials may have various appearances. They may occur transverse or inclined to the direction of rolling, as shown in A and B of Fig. 4 — or (if in the rolling direction) may show a number of transverse cracks as at C. C-shaped flaps may occur without passing through the center of the bulge, depending upon the location of the defect (Fig. 4D and E).

Similar considerations hold true for other sheet metals and alloys such as copper, nickel, monel and stainless steel. For these, like aluminum, bulge testing proved to be a method of important sensitiveness. However, many experiments are still required to explore all the possibilities. Thus, bulge testing might well give significant data pertaining to the formability of sheet metals.

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4. "Circular Bulging of Aluminum-Alloy Sheet at Room and Elevated Temperatures", by G. Sachs, G. Espey and G. B. Kasik, *Transactions* of the American Society of Mechanical Engineers, Vol. 68, Feb. 1946, p. 161-173.

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Personals

Robert J. Nekervis has been appointed to supervise the metallurgical development and **Robert M. MacIntosh** the chemical development of the newly established Tin Research Institute, Inc., in Columbus, Ohio. Both men were formerly with Battelle Memorial Institute.

Howard E. Pellett, formerly metallurgist with Republic Steel Corp., has been appointed West Coast (San Francisco and Los Angeles) sales engineer for Riehle Testing Machines Div. of American Machine and Metals, Inc.

R. M. Walker, Jr., has joined Electro-Alloys Div. of American Brake Shoe Co., Elyria, Ohio, as sales engineer for the Michigan territory. His headquarters will be in Detroit.

Melville D. Johnson has been promoted to vice-president of the Purolator Products, Inc., Newark, N.Y.

Douglas P. Tracy, formerly metallurgist of Detroit Tube and Steel Co., is now assistant superintendent of seamless tube mills for the Youngstown Sheet and Tube Co., Youngstown, Ohio.

George McB. Peters is now associated with Allegheny Ludlum Steel Corp. as sales representative in its Buffalo, N. Y., office.

Paul R. Wilt, formerly senior metallurgist at the Glenn L. Martin Aircraft Co., Baltimore, Md., is now with the Boeing Airplane Co., Wichita, Kan.

Roy Ohno, formerly chemist with Yale & Towne Mfg. Co., now holds a similar position with the General Electric Co., Pittsfield, Mass.

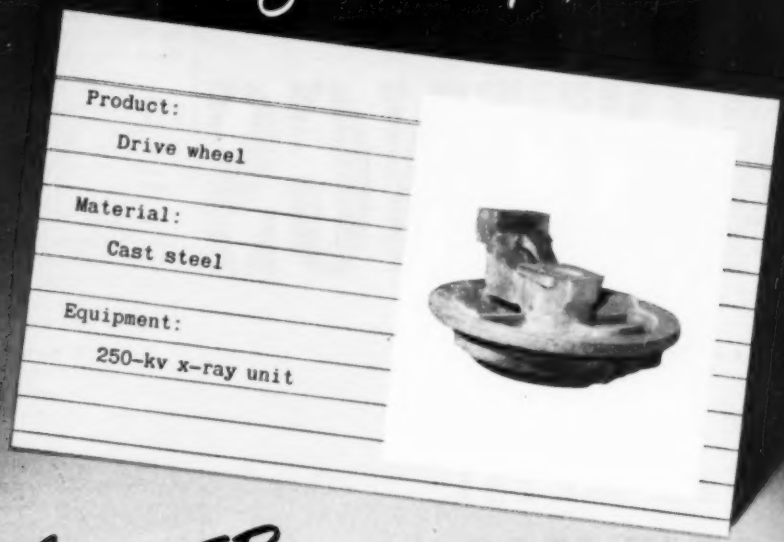
Albert M. De Gaeta, formerly at Texaco's Beacon Laboratories, is now a mechanical engineer at the New York Naval Shipyard, Brooklyn.

G. A. Greenamyer announces the opening of his business of manufacturers' representative in Philadelphia, at present representing Buffalo Stainless Casting Corp. and American Aluminum Casting Co.

Robert C. Bramlette, a recent graduate of Vanderbilt University, is now with the American Cast Iron Pipe Co., Birmingham, Ala.

I. R. Lane, Jr., formerly with the Seaboard Air Line Railway Co., is now metallurgist at the Eastern Experiment Station of the U. S. Bureau of Mines, College Park, Md.

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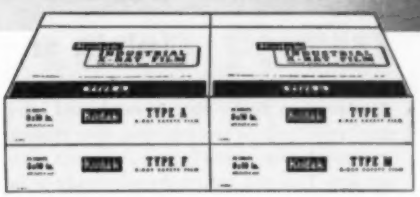
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W. E. Kuhn has recently been appointed associate metallurgist of the Titanium Alloy Mfg. Div. of National Lead Co., Niagara Falls, N. Y.

Louis T. Friedman, formerly assistant professor of engineering at Champlain College, has joined Sam Tour & Co., New York City, as head of the metallurgical engineering department.

Raymond J. Donley, graduate in metallurgical engineering from the Michigan College of Mining and Technology, has joined the physical metallurgy research staff of Battelle Memorial Institute, Columbus, Ohio.

William E. Borbonus, president of R-S Products Corp., Philadelphia, has been elected president of the Industrial Furnace Manufacturers Assoc., Inc.

Nat Levin, **John H. Garger**, and **James P. Moran**, all formerly of the Induction Heating Corp., have formed the High Frequency Foundry Sales Corp., New York City, which will act as sales representatives for the Thermex Division of the Girdler Corp., Louisville, Ky.

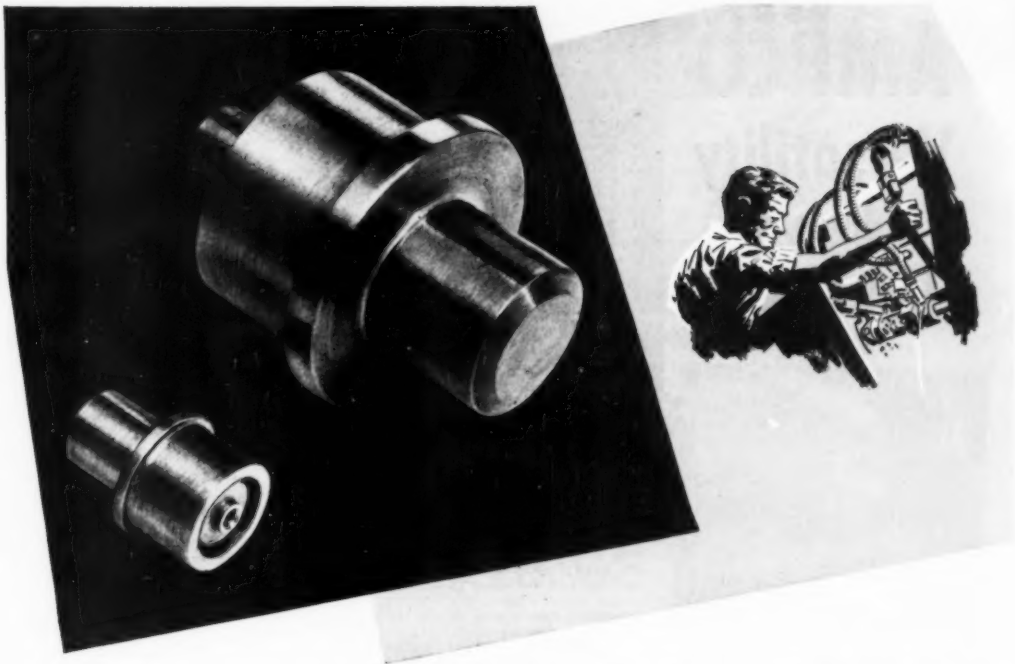
Heatbath Corp. announces the appointment of **William P. Fitz-Randolph** as technical director of sales. Mr. Fitz-Randolph was formerly technical sales and service representative of the American Cyanamid Co.

SKF Industries, Inc., announces the appointment of **C. E. Hammond** to the position of quality engineer of the Shippensburg, Pa., division. Mr. Hammond joined the company in 1947 as a time study engineer.

Henry Heyn, of Surface Combustion Corp., **Matt Snodgrass** of the Gas Machinery Co., and **Charles Kentnor, Jr.**, of the W. S. Rockwell Co., have been elected directors of Industrial Furnace Manufacturers Assoc.

George B. Waterhouse, past-president of the American Society for Metals and professor emeritus of metallurgy at Massachusetts Institute of Technology, has recently been awarded an honorary degree of Doctor of Engineering by Nova Scotia Technical College.

Ernest E. Graham has been appointed a sales representative for the Cooper Alloy Foundry Co., Hillside, N. J. He will serve Texas, Oklahoma and Louisiana from his headquarters in Houston, Texas.



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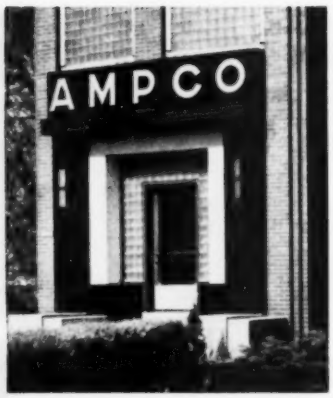
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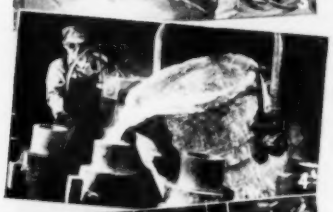
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Effects of Internal Stresses

IN previous issues of *Metal Progress* the first 21 papers in the "Symposium on Internal Stresses in Metals and Alloys" (Institute of Metals, London, 1948) have been reviewed. The next section of the Symposium, consisting of nine papers on effects associated with internal stresses on a microscopic and submicroscopic scale, is considered here.

This section begins with Professor Lawrence Bragg's paper concerning effects on a microscopic scale. The paper is so short (six pages, eight references) as to be quite disappointing. It is by no means sufficient to state that "certain simple assumptions lead to [Equation 1]". Also, a value of 0.0026 corresponds to 9 minutes of arc, not 15 as stated. The equation of Dean and Mann, which is not yet available in its published form, is given without much explanation, and further simplifications are taken *ad hoc*.

Then Professor Bragg proceeds to compute the shear strength (instead of the shear yield) for five metals in the cold rolled state (how much cold rolled?) and declares that the figures obtained are of the proper order of magnitude. But how proper? No doubt, 16.5 tons per sq.in. for copper and 6.7 for iron are neither ten times greater nor ten times smaller than the true values may be. But it is hard to assume that copper is two and a half times stronger in shear than iron and that even silver is stronger than iron.

Professor F. C. Thompson's paper examines the internal stresses arising from transformations in metals and alloys (six pages, 18 references). It is a purely qualitative statement of micro-observations made by various authors on metals and alloys and of the hypotheses explaining such unexpected features as the retention of austenite in the center of water-quenched bars of high-carbon steels, while the outside is largely transformed to martensite. In addition to the examination of strains in the austenite-martensite transformation, the author discusses the strain lines obtainable in the purest samples of chill-cast zinc and cadmium, such strains indicating the presence of allotropic changes at low temperatures (these changes were considered absent so far). *(To p. 96)*

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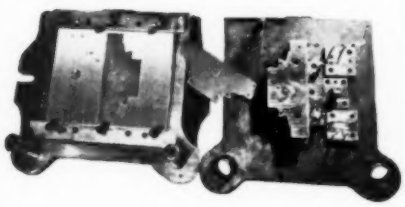
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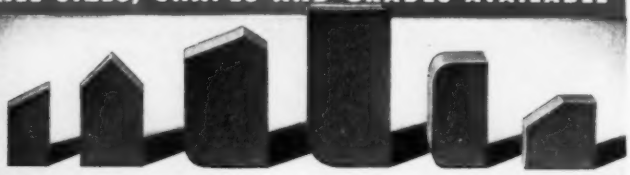
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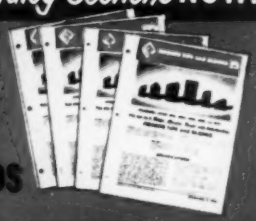
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Stresses

(Cont. from p. 94) Analogous strain lines are formed in quenched aluminum-copper alloys.

C. C. Earley contributed a small paper on the effect of internal stresses on the rates of transformation in iron-nickel alloys (four pages, one plate, two references). It embodies, in the form of a super-excessively abbreviated report, the author's work on iron-nickel alloys up to 27% nickel. The method of attack consisted in X-ray back reflection studies plus dilatometric investigations. How much was done in both directions cannot be judged, for the author produces neither data nor graphs beyond 10% nickel. A dilatometric examination of the isothermal transformation in two samples of 7.5% nickel, one merely cooled to 690° C., the second annealed at 500° C. before isothermal transformation, produced graphs of analogous (but not coinciding) shape, and the author concludes that the strain due to the distorted lattice of alpha, as obtained in rapid cooling, does not cause the alloy to transform differently from the manner obtaining in an alloy in which the distortion was eliminated by prolonged annealing.

F. R. N. Nabarro presented a report (14 pages, 56 references) on the state of our knowledge (or more appropriately—ignorance) regarding diffusion and precipitation. His paper cannot even be approached by a reader who is not fully steeped in a number of hypotheses, as for instance the presence of full atoms, ionized atoms and holes in the crystal lattice. One has to be able to visualize a molecule consisting of a hole in space plus the atom A (or its ion). After one succeeds in doing this trick, it becomes "easy to see that such a molecule can wander freely through the lattice". Why "easy"? And how easy? This "it is easily shown" appears too frequently in papers by theorists. It does not help a bit to understand the subject.

E. C. W. Perryman contributed a brief paper (six pages, four references) on the effect of cold work on the rate of precipitation in aluminum alloys with 7% magnesium, with 8% magnesium plus 1% zinc, and with 3½% magnesium plus 4½% zinc. The work consisted exclusively in microscopic and hardening investigations. The quite definite conclusions. *(To p. 98)*

CHEMICAL USERS' GUIDE To General Chemical Products for the Metal Industries

PRODUCT	AVAILABLE FORMS	COMMERCIAL STRENGTHS	SHIPPING CONTAINERS	APPLICATIONS
Sulfuric Acid H_2SO_4	Liquid	66° Be (93.19%) 99% Oleum, 20-65%	Carboys (except Oleum) Steel Drums Tank Trucks Tank Transports Tank Cars	Pickling and descaling; electroplating; bright dipping; electrolytic polishing; galvanizing; anodizing.
Hydrochloric Acid HCl + water (Muriatic Acid)	Liquid	18° Be (27.92%) 20° Be (31.45%)	Carboys Tank Trucks Tank Cars	Pickling; electroplating; bright dipping; galvanizing; tinning; etching metals; dissolving metals.
Nitric Acid HNO_3 + water	Liquid	36° Be (52.30%) 38° Be (56.52%) 40° Be (61.38%) 42° Be (67.18%) 95%	Carboys (except 95%) Drums Tank Cars	Pickling; electroplating; bright dipping; oxide finishing; dissolving and stripping metals.
Hydrofluoric Acid HF + water	Liquid	30% 60% 48% 70% 52% 80%	Rubber Drums (except 60%) Steel Drums & Tank Cars (60% only)	Pickling; electroplating; electrolytic polishing; bright dipping.
Sodium Fluoride NaF	White Powder	90 or 95% Light or Dense	Fibre Drums	Manufacture of rimmed steel; heat treating; galvanizing; pickling; electroplating.
Sodium Bifluoride $NaHF_2$	White Powder	90%	Fibre Drums	Electroplating.
Trisodium Phosphate $Na_3PO_4 \cdot 12H_2O$ (TSP)	Crystal	P_2O_5—18.4%	Multiwall Paper Bags Fibre Drums	Alkali cleaning.
Sodium Metasilicate $Na_2SiO_3 \cdot 5H_2O$	White Granules	98.5%	Multiwall Paper Bags Fibre Drums	Alkali cleaning.
Oxalic Acid $C_2H_2O_4 \cdot 2H_2O$	Colorless Crystals	99.5%	Fibre Drums	Oxide finishing; metal cleaning.
Potassium Fluoborate KBF_4	White Powder	97.0%	Fibre Drums	Aluminum and magnesium casting; as a flux and grain refiner for aluminum; for removing magnesium from secondary aluminum alloys.
Sodium Fluoborate $NaBF_4$	White Powder	94.0%	Fibre Drums	
Ammonium Fluoborate NH_4BF_4	White Powder	96.0%	Fibre Drums	Aluminum and magnesium casting; electroplating.
Fluoboric Acid HBF_4 + water	Liquid	42.0%	Rubber Drums	Electroplating; metal cleaning or dipping.
Lead Fluoborate $Pb(BF_4)_2$ + water	Liquid	51.0%	Carboys	Electroplating.
Nickel Fluoborate $Ni(BF_4)_2$ + water	Liquid	44.0%	Carboys	Electroplating.
Tin Fluoborate $Sn(BF_4)_2$ + water	Liquid	46.0%	Rubber Drums	Electroplating.
Zinc Fluoborate $Zn(BF_4)_2$ + water	Liquid	49.0%	Rubber Drums	Electroplating; bonderizing aluminum.
Copper Fluoborate $Cu(BF_4)_2$ + water	Liquid	44.0%	Carboys	Electroplating.

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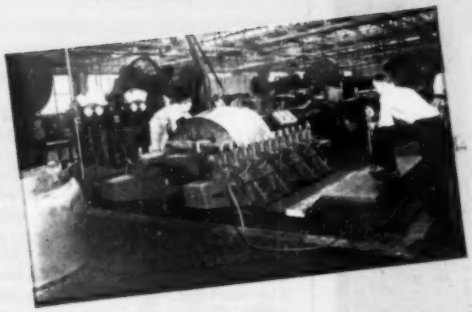
Stresses

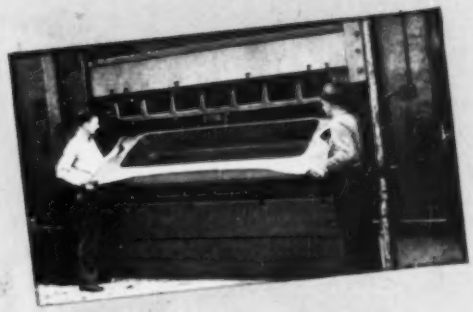
(Conl. from p. 96) are that samples overstrained even to the extent of only 2% harden on artificial aging to a greater extent and more rapidly than the samples that were not so strained. Further, that the precipitation along grain boundaries is far more intensive in strained samples than in those which were not prestrained. On the other hand, these prestrained and more rapidly hardened samples show a far shorter life under stress-corrosion, which the author explains by the greater continuity of the precipitated network along the grain boundaries.

This short contribution has the advantage of being quite clear and of practical value. It corroborates the facts known in many other instances, but apparently rarely adhered to by the practical men, namely, that precipitation hardening must be used with plenty of judgment. Sometimes, a rapid aging plus an intermediate overstrain (cold work after solution heat treatment) will give good service; but in many more instances, an aging at the minimum temperature possible and a careful abstaining from the intermediate cold working will produce material of a far greater endurance as well as longer life under adverse conditions.

We come now to the paper by M. L. V. Gayler on age hardening (13 pages, 38 references). Miss Gayler's extensive work on the age hardening of aluminum alloys, especially the 4% copper alloy, leads her to propound a rather distinct theory of hardening. She finds that the process takes place, at any temperature, in two stages with a stationary state between. According to her, the first stage of hardening is caused by strains introduced by the migration of atoms of copper and the second by the formation of copper-rich platelets on the planes of precipitation. The first stage of the process leads to an increase in resistivity and a moderate strain, while the second stage increases the strain (completes the hardening) and decreases the resistivity.

Miss Gayler mentions, of course, other theories of age hardening, and among these the theory of U. R. Evans of a redistribution from random to ordered positions of the solute atoms as the cause of hardening, and the formation of crystallized (three-dimensional) particles of the precipitate *(Cont. on p. 100)*





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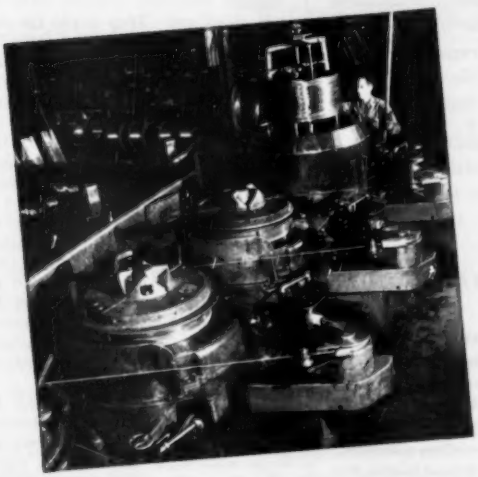
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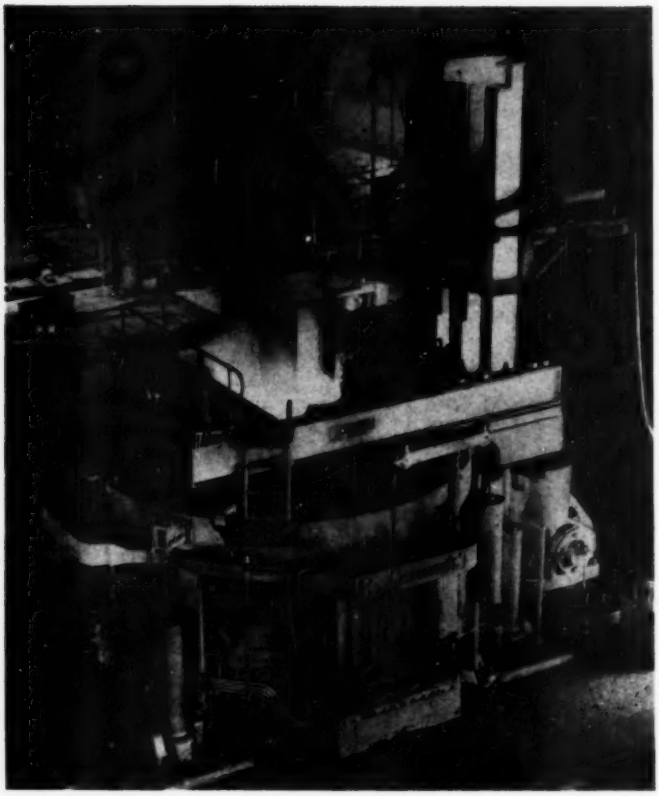
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Stresses

(Cont. from p. 98) as the cause of softening after the peak of hardness is passed.

Professor J. H. Andrew's paper on internal stresses and the formation of hair-line cracks in steel (nine pages, five references) deals in a brief, undecisive manner with the summary effects of occluded molecular hydrogen and the internal stresses, which might — if reaching the proper magnitude — cause hair-line cracks. Cold worked steel, subjected to high hydrogen pressures in pickling or electroplating, might dissolve monatomic hydrogen and precipitate it later in various cavities, especially in the boundary regions between the mosaic blocks. This would certainly cause a tendency toward embrittlement and might cause cracking at ordinary temperatures without any external stress being applied.

Professor Andrew states quite plainly, of course, that the subject requires a great deal of study. Meanwhile, metallurgists all over the world are already fully aware of the necessity to cut down the access of hydrogen to their steels.

F. P. Bowden reported on the experiments of W. Boas and R. W. K. Honeycombe on internal stresses caused by anisotropic thermal expansion of pure metals and alloys (six pages, 11 references). The investigation was started by Boas and Honeycombe when it was noticed that a tin-base bearing alloy passing through many cycles of heating and cooling developed a network of surface distortions, while a lead-base bearing alloy did not show any. They made the logical assumption that the grains of tin, being anisotropic, were unable to expand and contract in perfect accord and developed stresses that were beyond the yield point of the alloy, while lead, being highly isotropic, could not develop such stresses, even though its alloys have lower yield points.

To prove their theory, they investigated other anisotropic metals — mainly zinc and cadmium, but also magnesium. The first two reacted much more sharply than did tin, but magnesium, though having the same type of crystal structure, apparently suffered no distortions due to thermal stresses.

The paper is accompanied by beautiful micrographs illustrating the phenomena studied. However, it is somewhat difficult to agree with the author *(Cont. on p. 102)*

Economy in Production

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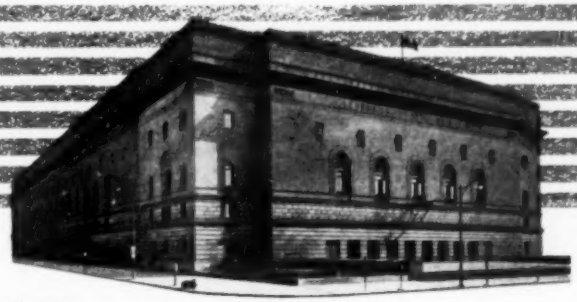
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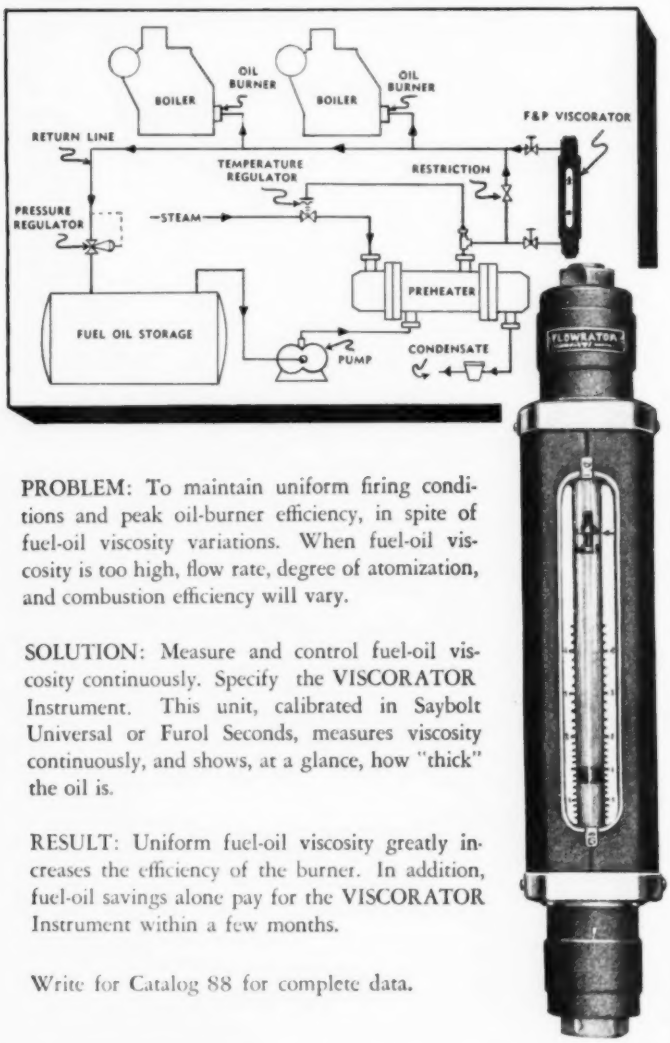
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Stresses

(*From p. 100*) when he states that thermal stresses plus fluctuating mechanical stresses might lead to a *failure* in a bearing. One must bear in mind that the phenomena studied by Boas and Honeycombe on metals — not on alloys — were of a strictly plastic nature, while in the usual bearing alloys, containing a hard constituent, the plastic distortion would scarcely be comparable. Tin-base bearing alloys have been used with most satisfactory results for over a century, and the lead-base bearing alloys, which, being cubic, cannot show that distortion, would probably not be used at all, were it not for the scarcity of tin.

B. Sugarman's paper on the photoelastic approach to stress modifications caused by inhomogeneities (12 pages, no references) contains some beautiful polarized-light photographs of stress distribution in bent strips of a special plastic. The distinctive feature of his illustrations is the use of perforations, either hollow or plugged by stronger substances, in order to show how the uniformity of stress distribution ceases and spots of stress concentration appear. However, the author does not add a single quantitative illustration, so the reader remains at a loss to understand the magnitudes of the stresses accounting for the number of fringes shown and would hardly be able to make the slightest use of Sugarman's paper in order to gain some insight into the distribution of stresses around defects and particles of other constituents or inclusions.

All told, it is rather unfortunate that the photoelastic methods, though useful (perhaps) to the designer, remain as a sort of icing on the cake as far as the metallurgist and metal physicist are concerned.

M. G. Corson

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*Abstracted from "The Part Played by Oxygen and Nitrogen in Arc Welding", by J. D. Fast, *Philips Technical Review*, Vol. 10, 1948, p. 27-34.

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447. Alloy Steels

New 8-page engineering data bulletin describes Nitralloy, special alloy steel suitable for extreme wear and abrasion resistance. *Joseph T. Ryerson & Son, Inc.*

448. Alloy Steels

Manganese-Titanium steels show a low sensitivity in the weld notch test. Mn-T steels produce better structural and plate sections. Write for detailed information on the latest developments and technical advice on their applications. *Titanium Alloy Mfg. Div.*

449. Aluminum Finishes

Attractive new 124-page booklet furnishes basic information on the various processes for applying surface finishes to aluminum. *Reynolds Metals Co.*

450. Aluminum Handbook

A new, handy 24-page book contains a compilation of important aluminum industry specifications including ASTM, AMS, SAE, Federal, etc. Sent free on request for "Aluminum Alloys, U.S. Standard Specifications". *Federated Metals Div.*

451. Aluminum Strip

New price and data sheets available on Revere aluminum strip give prices on different alloys, together with limits of manufacture and location of offices and mills where stocked. *Revere Copper & Brass, Inc.*

452. Band Filing

New DoAll band filer assures higher speed production in all types of precision filing work. Described in bulletin 48-400. *DoAll Company.*

453. Bars, Steel

Send for full information on Republic cold drawn alloy steel bars available in all standard shapes and sizes, furnace-treated to meet your specific requirements. *Republic Steel Corp.*

454. Brazing

Easy-Flo simple, versatile method of fabricating ferrous, nonferrous and dissimilar metals described in bulletins 12-A and 15. *Handy & Harman.*

455. Brazing Alloy

Extruded Phos-Copper, the uniform brazing alloy for copper, brass and bronze, is discussed in new 15-page booklet along with recommended fluxes and "know how" of the process. *Westinghouse Electric Corp.*

456. Castings

New 40-page well-illustrated booklet, "Help Calumet Steel Make Your Castings Better", gives a practical summary of information needed to purchase electric furnace steel castings wisely and economically. *Calumet Steel Castings Corp.*

457. Castings

Bulletin 30 outlines a series of production and specification problems solved through use of Meehanite castings. *Meehanite Metal Corp.*

458. Castings

20-page booklet "Misco Precision Castings", contains valuable technical information for manufacturers requiring small, accurate alloy steel parts in quantity. *Michigan Steel Casting Co.*

459. Castings

Complete information on numerous applications for microcasting given in 16-page booklet, "New Horizons for Microcasting". *Austenal Laboratories, Inc.*

460. Castings

Interesting booklet on Accumet Castings tells how these versatile castings lower your unit production costs and permit the use of materials which are difficult to forge or machine. *Crucible Steel Co. of America.*

461. Castings

New booklet "Haynes Precision Castings", describes how precision investment-casting process makes possible liberal use of such design features as thin edges, fillets, irregular holes, and intricate contours. *Haynes Stellite Co.*

462. Castings, Alloy

New bulletin describes Pyrasteel grids designed and built for endurance and permanence. *Chicago Steel Foundry Co.*

463. Castings, Alloy

New bulletin, "Solving Corrosion Problems with Chem-Alloy High-Alloy Castings", features two important charts, a quick selector for corrosion resistance of most commonly used alloys and a list of types and grades in standard alloys. *Electro Alloys Division.*

464. Castings, Aluminum Alloy

Well-illustrated 80-page reference manual is now available with full information on the uses of Permite aluminum alloy castings. *Aluminum Industries, Inc.*

465. Castings, Steel

New table of classifications for steel castings groups them according to tensile strengths for easy reference. *Steel Founders' Society of America.*

466. Cleaning, Machine

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467. Corrosion Control

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468. Cutting Oils

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469. Cutting Tools

New Firthite Tips and Blanks catalog 60-010 covers specification data, list prices and items stocked for all grades and sizes. *Firth-Sterling Steel & Carbide Corp.*

470. Die Casting

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471. Die Castings

Revealing book "How Magnesium Pays" gives case studies of its economical use in a wide range of products. *Dow Chemical Co.*

472. Drawing Compounds

New leaflet available on several recently developed compounds made especially for use on different types of metals in stamping or drawing operations. *E. F. Houghton & Co.*

473. Electroplating

Metal Fluoborate Solutions are described in technical bulletin ZF-1, which outlines new approach to zinc plating. Bulletin LTF-1 describes lead-tin alloy plating from Fluoborate Bath and Manual CF-1, copper fluoborate. *General Chemical Div.*

474. Extrusions

"Alcoa Aluminum Impact Extrusions" is the title of a new booklet giving up-to-date information on short-cuts to designing all types of parts by means of these new impact extrusion presses. *Aluminum Co. of America.*

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Full details on black magic finishes for steel, iron, zinc, cadmium, copper and its alloys, given in new "Black Book". *Mitchell-Bradford Chemical Co.*

476. Finishing

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Attractively illustrated 20-page booklet gives complete details on new electronic universal flame hardener. *Stearns-Roger Mfg. Co.*

478. Forging

New 64-page booklet features pictorial review of forging operations on parts for freight cars, automotive, and farm implements. Facilities of two well-known forging plants described. *Pittsburgh Forgings Co.*

479. Forging

New 60-page well-illustrated catalog outlines the selection of metals for forgings and follows the various steps in production from blast furnace to finished forging die. *Drop Forging Assn.*

480. Forgings

Bulletin 65-C describes forgings being produced better, faster and at lower cost by high-production, heavy forging machines. *Ajax Manufacturing Co.*

481. Forgings

"Improvement of Metals by Forging", a new 44-page catalog, provides one of the most comprehensive references on forging characteristics, designs and applications. *Steel Improvement & Forge Co.*

482. Furnaces

Catalog 110 features new heat treating furnaces and atmosphere charts. *C. I. Hayes, Inc.*

483. Furnaces

Bulletin 53 tells how new cyclone furnace can help reduce costs and improve quality of tempering, annealing, nitriding, and nonferrous heat treating. *Lindberg Engineering Co.*

484. Furnaces

New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co.*

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HY-TEN and AISI

Arc Welding

(Cont. from p. 102) and nitrogen in liquid iron between the melting point and boiling point, *(b)* solubility of oxygen and nitrogen in solid iron, particularly alpha, to gain some insight into the effects of these gases on the mechanical properties of welds, and *(c)* the chemical reaction between carbon and oxygen dissolved in liquid iron.

When iron reacts with oxygen at high temperatures, saturated solutions are obtained at oxygen pressures far below the partial pressure of this gas in air. In the consideration of nitrogen, the reverse is shown to be true; at high temperatures the state of saturation for solid and liquid iron is reached only at pressures far above the partial pressure of nitrogen in air.

Extrapolation of Chipman and Fetter's curves gives a maximum solubility of 1.2% oxygen at temperatures near boiling (about 2750° K.). Results from Losana's experiments on welding with bare wire of different diameters showed an oxygen content between 0.140 and 0.953%. Higher oxygen and nitrogen contents were associated with the smaller diameter wire, probably because of smaller droplets, which would give higher temperatures and would present more surface for contact with the gases.

From other experimental work the author calculates a solubility of 0.065% nitrogen at the boiling point with a nitrogen pressure of 0.8 atm. Actual analyses show nitrogen contents three to four times this. The explanation lies in the fact that much higher temperatures (6000° K. at least) exist in the arc. At these temperatures the concentration of atomic nitrogen in the gas phase is already about 10^5 times that existing at the boiling point of iron, and much greater nitrogen contents are possible. As shown in the solubility curve of Fig. 1 (page 108), much of this is released in cooling from liquid to solid and is one of the chief causes of porosity.

Porosity — Highly porous beads are obtained in welding with bare electrodes. The accepted explanation for weld porosity has blamed carbon monoxide formed in the reaction between oxygen absorbed during welding and the carbon present in the electrode. Experimental work in the welding of carbon-free iron plate with carbon-free bare wire showed practically the same amount *(Cont. on p. 108)*

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Arc Welding

(From p. 106) of porosity found in welding 0.1% carbon material. Obviously the release of dissolved nitrogen is a further cause of porosity.

Impact strength of welds made with bare wire is very low because of porosity and high oxygen and nitrogen contents. Welds made with modern coated electrodes have much lower gas contents, although 0.005 to 0.033% nitrogen and 0.03 to 0.12% oxygen are encountered, depending on the type of rod. Since both oxygen and nitrogen contents vary in the same direction, it is impossible to study their separate effects on the impact strength of welds. By high-frequency melting under argon and adding known amounts of oxygen or nitrogen, it was found that up to 0.033% nitrogen (the maximum found in deposits from modern coated electrodes) does not affect the impact value. The addition of 0.12% oxygen is accompanied by a gradual lowering of impact strength. It is indicated that the great influence of oxygen on the impact strength is caused by the oxide, which is partly contained along the grain boundaries.

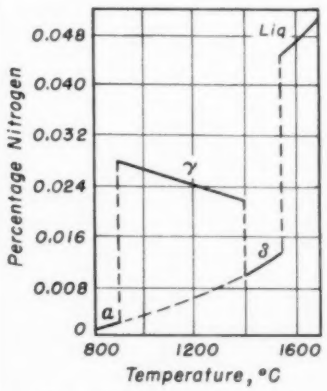
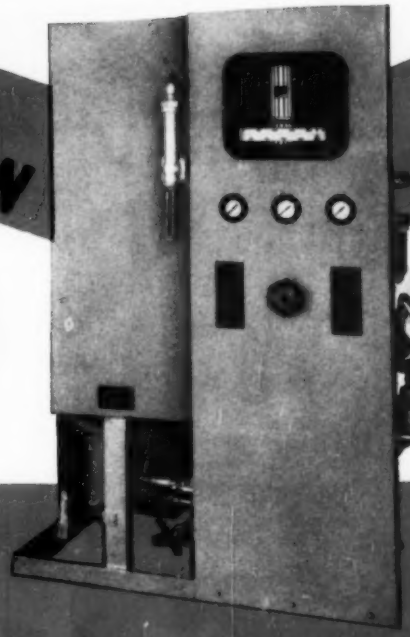


Fig. 1—Solubility of Nitrogen in Iron at 1 Atm. Nitrogen Pressure.

Aging Strain aging and quench aging have been attributed to both oxygen and nitrogen. Experiments with steels containing oxygen and nitrogen separately show that nitrogen is the cause. The solubility curve of Fig. 1 indicates that it is probably a precipitation phenomenon accelerated by slightly higher than normal temperatures or straining after rapid *(Cont. on p. 110)*

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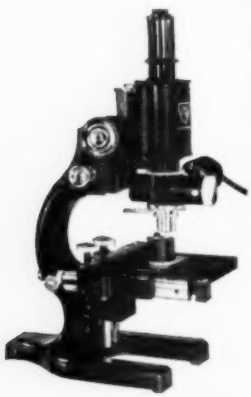


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Arc Welding

(Cont. from p. 108) cooling from a temperature of greater nitrogen solubility.

Useful effects of oxygen and nitrogen are twofold: first, better heat transmission as a result of dissociation of gases in the arc (which requires high energy input) and subsequent recombination with high energy release at the electrode surface; second, the action of oxygen on carbon to form carbon monoxide explosions which shoot the metal away from the electrode. Experimentally, overhead welding was found to be impossible with bare wire containing no carbon. Droplets formed but merely ran down the electrode. Other investigators have reported that when welding with bare electrodes in helium, argon or nitrogen, there is no arc blow, no crater, and little penetration. A few per cent of oxygen added to the inert gas gave the normal welding crater and penetration.

Welding-Rod Coatings

IN the welding of steel with bare wire it was shown (see preceding abstract) that the propelling force across the arc was the reaction forming carbon monoxide; without this reaction, overhead welding is impossible. The author shows experimentally that the gases contained in the alkaline earth carbonates provide the motive force for metal transfer in welding with coated electrodes. After being heated to drive off chemically bound H_2O and CO_2, an electrode normally suited for overhead welding becomes completely useless because no metal is transferred to the work piece.

With high iron oxide coatings CO porosity is a problem. The author shows that at high temperatures oxygen can be picked up from pure SiO_2 slag. This slag is also permeable to oxygen and nitrogen; however, because of the short reaction time, equilibrium conditions are not achieved in the slag or in the slag-covered metal puddle.

Requirements to be met by coat-

(Continued on page 112)

*Abstracted from "The Function of the Coating of Welding Rods", by J. D. Fast, *Philips Technical Review*, Vol. 10, 1948, p. 114-122.

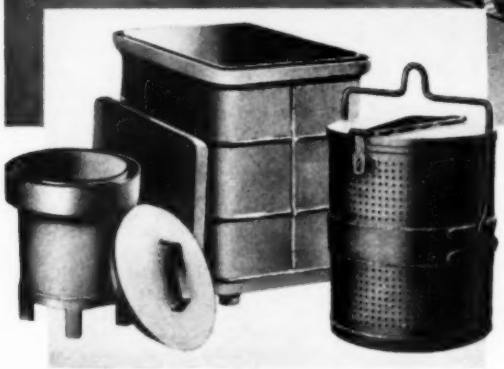
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By cutting 2/3 off the weight of annealing equipment, The Pressed Steel Co. units have, in some plants, shortened annealing cycles as much as five hours. And, because of their light weight, they also save substantially in handling time. Records of some installations show total savings of thousands of hours.

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"Pressed Steel" light-weight sheet alloy heat-treating units are furnished in any size, design or metal specification: boxes, covers, baskets, racks, tubes, retorts, etc. As pioneers of welded alloy heat-treating equipment, we offer you a wealth of experienced engineering assistance and production know-how. Send blue prints or write as to your needs.

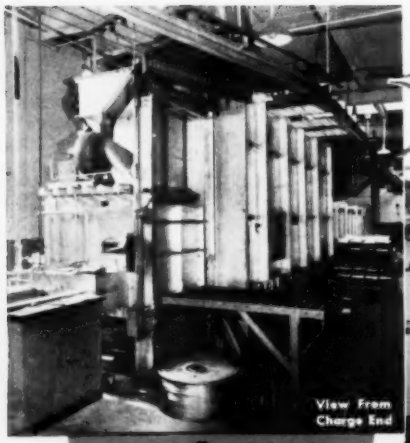
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THE PRESSED STEEL COMPANY

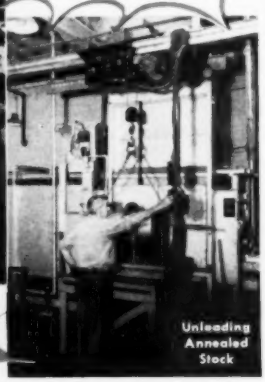
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Welding Rods

(Continued from page 110)

ings and slag are: *(a)* proper melting range of the coating (1200 to 1300° C.) to give a cup of correct length, *(b)* coating constituents that will provide arc re-ignition in a-c. welding, *(c)* proper gas evolution from the coating to give correct penetration, *(d)* alloying action required from the coating when deposits richer in certain elements are desired, *(e)* slag viscosity neither too high nor too low for metal protection, *(f)* surface tension of the slag neither too high nor too low, for the same reason, *(g)* expansion coefficient of the slag as different as possible from that of the metal, for easy removal, and *(h)* high welding speed and suitability for all positions of welding.

Four main types of electrode coatings are described by the author:

1. High iron oxide slags which also contain quartz, natural silicates, manganese oxides, and sometimes titanium dioxide (rutile). Calcium and magnesium carbonates promote electron emission and provide gas flow for metal transfer and penetration. Because of the high iron oxide content, oxidation and porosity of the weld metal are nearly as high as in bare welding, although nitrogen content is low.

2. Coating as above but with reducing agents such as ferromanganese or ferrosilicon. (Ferrosilicon is not commonly used in this country.) Exothermic reactions between the oxides and reducing compounds increase welding speed and, if properly balanced, reduce oxygen and nitrogen contents to acceptable levels. The oxygen content is about 0.12%. (A.W.S. classifications 6020 and 6030 cover this type.)

3. To further improve mechanical properties, iron oxide is avoided entirely and oxides with high heats of formation such as CaO are used. Fluorite (CaF_2) is added as a fluxing agent. Water glass and reducing ferro-alloys are also added. Very low oxygen (about 0.03%) is obtained in the deposit. Arc extinction in a-c. welding caused by the fluorite is a source of trouble and the Philips company markets a rod with a "shell-type" coating,* which is applied in two *(Cont. on p. 114)*

*A.W.S. 6015 (d.c.) and 6016 (a.c.-d.c.) classifications cover this type, which is commonly known as the ferritic electrode. The low hydrogen content reduces underbead cracking in welding high-tensile steels. Common practice in this country is to add potassium salts for a-c. arc stabilization.

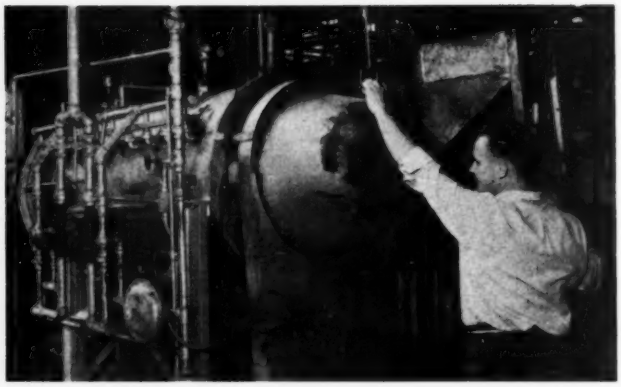


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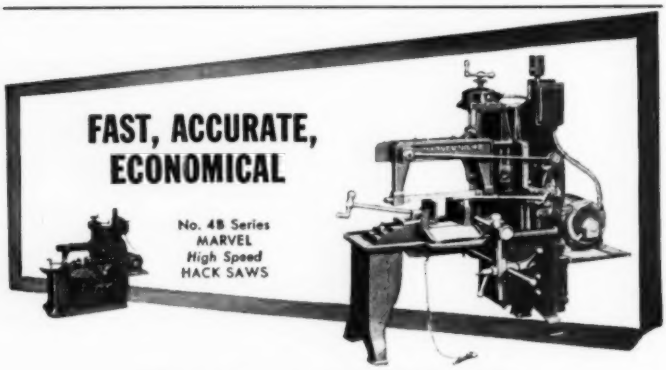
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Welding Rods

(From p. 112) layers with fluorite on the outside to reduce this difficulty.

4. Coatings containing large quantities of organic matter in combination with the slag-forming ingredients of 1, 2 and 3. The oxygen content is between 0.03 and 0.12%.★

Also described is a method of incorporating iron powder in the coatings, which permits a more variable arc length to be used.

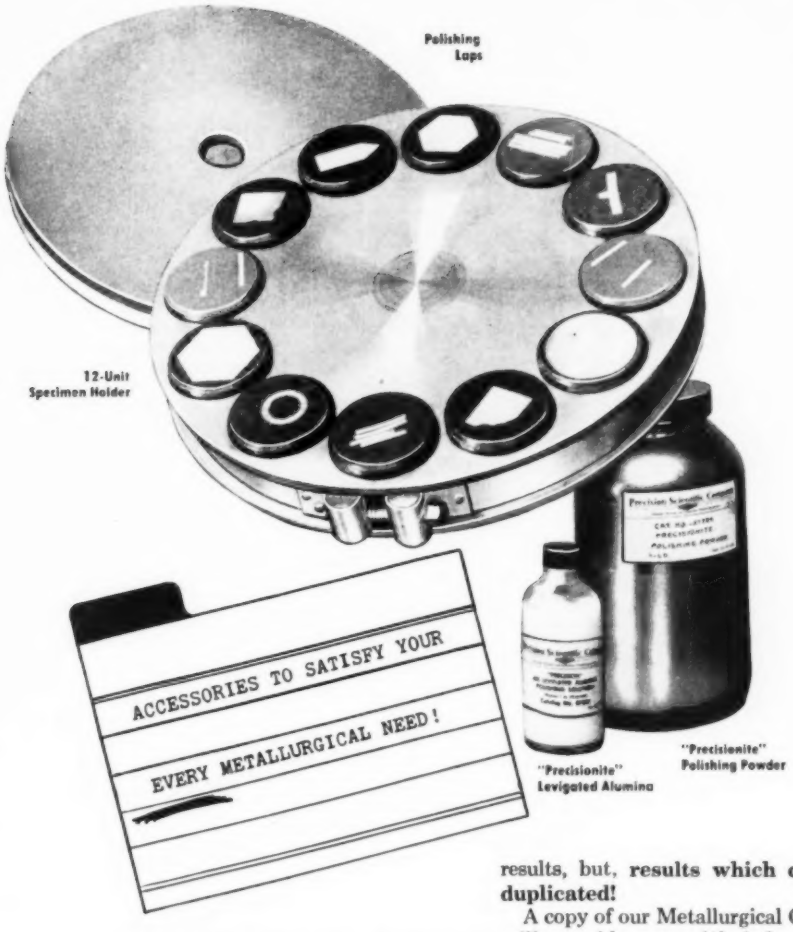
The nitrogen content of deposits from coated wires varies, Type 2 deposits commonly running about 0.03% and Type 3 deposits about 0.01%. Gas analyses of pulverized slag collected from these types and heated by high frequency under vacuum showed the Type 2 slag to contain 10% nitrogen by volume and the Type 3 slag 1% by volume. It was assumed that the higher nitrogen content of the Type 2 slag is related to the higher nitrogen content in the deposit.

Ultrasonic Inspection†

THE ABSORPTION of ultrasonic vibrations of 2×10^6 to 10^9 cycles per sec. is greater in nonhomogeneous metals than in homogeneous metals. Coarse-grained structures are more absorbent than fine-grained structures. The amount of absorption depends on the grain size, the grain orientation, and the wave length λ of the vibration. If the grain size is equal to or greater than λ, absorption is very great because of diffuse scattering. When a frequency of 18×10^6 was used, the absorption of ultrasonic impulses by steel specimens was found to increase almost directly with increase in the average grain size. Specimens of markedly anisotropic Armco iron were found to absorb completely the ultrasonic impulses perpendicular to the elongated grains while transmitting the impulses along the grains. At a lower frequency, 4×10^6, the ultrasonic waves were transmitted in both directions. By means of the impulse ultrasonic defectoscope, devised *(To p. 116)*

★A.W.S. designations 6010 and 6011 cover this type.

†Abstracted from "Application of Ultrasonics in Engineering and Physics", by S. Ya. Sokolov, *Zavodskaya Laboratoriya*, Vol. 14, 1948, p. 1328-1335. (In Russian.)



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Ultrasonic Inspection

(Cont. from p. 114) in the author's laboratory, it is possible to "see through" metal thicker than 10 meters and to detect small defects. In order to do this, it is necessary to match suitably the intensity and wave length of the ultrasonic vibrations.

The instrument has been perfected over a period of 20 years. From 1927 to 1935 continuous ultrasonic vibrations were employed in the instrument. The second stage of development was the use of ultrasonic impulses in 1935, with impulses of the order of 10 microsec. Later improvements permitted the length of impulse to be reduced, until now 0.4 microsec. can be obtained. This allows the detection of small defects (1 mm. in size) located in thick metal. The third stage in the development of the ultrasonic defectoscope consisted in undertaking to obtain a true magnified picture of the defective places in a metal on the screen of a cathode ray tube (ultrasonic microscope). The present equipment is an improvement of a method applied in the author's laboratory before the war. The separate quartz receiving disk in a liquid medium is at the focus of an acoustical lens and receives the ultrasonic impulses reflected from the defect. The quartz disk is mounted in a special cathode ray tube, and the piezo-electric charges on it change the secondary electron emission. After amplification, these emission changes are transferred synchronously to a second cathode ray tube, where they appear as the image of the defect.

The thickness of a hardened layer on a piece of steel can be determined by means of ultrasonic impulses. As a result of a difference in acoustical stiffness between the hardened and unhardened regions of the steel, a portion of the incident impulse is reflected at the interface between the hardened and unhardened steel. The reflected wave is recorded on a cathode ray tube.

A further use of ultrasonic vibrations is in the investigation of chemical reactions. In general, the velocity of propagation v and the coefficient of absorption α vary continuously as the reaction proceeds. Therefore, by measuring either v or α, the course of the reaction can be followed. The advantages of this *(Cont. on p. 118)*

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. . . Substantially cuts instrument costs

CONVENIENCE and ECONOMY distinguish this multiple control pyrometer . . . pioneered by **TAG** in the interests of lower costs and better processing control. Because of its high sensitivity and quick action its closeness of control equals that of single point instruments at less cost per point.

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PROPER DESIGN– still the most important ingredient

Despite the great advances in the use of alloy steels, the shape and proportions of a part are still of more vital significance than its material.

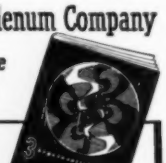
In an overall view, we should rate Design (1), the choice of the proper Steel (2), and its Treatment (3), in that order of importance. All are, of course, matters of great concern, but if the design is wrong then the proper choice of steel and its successful treatment serve no useful purpose.

What is the metallurgical significance of poor design? It promotes unhealthy stress concentrations and troublesome variations in the proportions of adjacent parts.

To stress the relationship of good design to metallurgical and economic factors, we have prepared a book helpful to designers, showing by sketches a great many factors in good and poor design which influence the behavior of a part in service.

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MP-7

Ultrasonic Inspection

(Cont. from p. 116) method are that reaction times from hours down to microseconds can be studied, and that the medium can be gas, liquid or solid, transparent or opaque.

Testing Cermets*

THIS is the fourth in a series of papers on cermets; the first three papers concerning early equipment and reactions of metals and oxides were published in the March 1949 *Journal* of the American Ceramic Society, and were abstracted in *Iron Age* for July 8, 1948.

The continued work on these combinations of metal powders and oxides, such as chromium and alumina, to obtain strong refractory products, resistant to thermal shock, requires that additional special equipment be developed. Equipment described in this paper includes: *(a)* a molybdenum-wound furnace for firing in inert atmospheres to 3300° F., *(b)* a diamond-wheel grinding machine, *(c)* a description of the modifications in a previously described tensile test machine, and *(d)* a telescopic type of thermal expansion apparatus.

The furnace has a 6-in. diameter Alundum tube with 86 ft. of 0.080-in. molybdenum wire wrapped around it and spaced so that, with radiation shields at each end, the temperature is within 5° F. over the central 20 in. of length.

In preparing tensile specimens, a modified lathe is used with a 7-in. diamond grinding wheel to prepare the hydrostatically pressed rods, which are ⅜ in. in diameter and 10 in. long. The rods are necked down in the center on a 4½-in. radius to give a ¼-in. minimum diameter.

The tensile test machine as previously described used pneumatic cylinders to load the specimen; however, this has been changed to utilize a cable-loaded lever system. The thermal expansion apparatus is of a well-known type built to hold bars 3¾ in. *(Cont. on p. 120)*

*Abstracted from "Equipment for Development and Testing of Cermet Solid Bodies", by T. S. Shevlin and A. R. Blackburn. Paper presented at the 51st annual convention of the American Ceramic Society, April 1949.

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MAN PRODUCTS

Testing Cermets

(From p. 118) long, lying horizontally in a tube 1 in. in diameter and 25 in. long, heated by electrical resistance elements of the silicon carbide type. The tube has two cross holes 4 in. apart for observing the specimen through telescopes.

Subzero Impact of Copper and Brass*

A 30-kg. Charpy impact machine was used to test standard 57 x 10 x 10-mm. specimens of copper and brass at −253, −196, and +20° C. (−423, −321 and +68° F.). The procedure for testing at −423° F. was the following: The specimen was cooled in boiling nitrogen (−321° F.) and was then transferred to a flask of boiling hydrogen (−423° F.). The specimen was forced along a tube from the hydrogen flask to a special fixture on the impact machine that lined up the notch to within 0.1 mm. The pendulum was automatically released, and the test was completed within 0.5 sec. after the specimen had been taken from the hydrogen bath. However, even during this short time the specimens began to decrease in temperature unless they were coated with flannel to slow down evaporation from their surfaces. Bare specimens could be used in the tests at −321° F.

The average values of impact strength in kg. per sq.cm. at −423° F. were:

Copper	21.6
Brass (LS-59)†	4.0
Brass (LS-62)†	16.2

The value for copper was slightly higher than that obtained at 68° F., 17.9, and the values for the brasses were slightly lower. This temperature variation of the impact strength parallels the variation of ductility in static tests. There was practically no change in the character of the fractures between +68 and −423° F.

*Abstracted from "Impact Strength of Metals at −253° C.", by V. I. Kostenetz, B. G. Lazarev, V. I. Khotkevich and M. G. Shikhman, *Zhurnal Tekhnicheskoi Fiziki*, Vol. 18, 1948, p. 1149-1155. (In Russian.)

†In a previous paper the composition of LS-59 was given as 59% Cu, 39.9% Zn, 1.1% Pb. LS-62 probably contains about 62% Cu, 37% Zn, 1% Pb.

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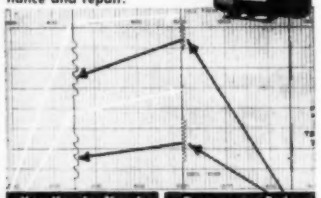
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Effect of Forging*

SOME surprising test results were obtained on the effect of pressure without plastic flow on cast steel ingots. The authors found that the ductility of pieces cut from as-cast ingots was definitely improved by subjecting them to high pressures at forging temperatures, even though the pieces were contained so that there was no plastic flow. The pressures were produced by hammering in a closed die mounted in a 5000-lb. steam drop hammer. The temperature of the pieces at the time of hammering was about 2200° F.

To make accurate comparisons the authors cut pieces from an ingot and compared the properties of these pieces with those obtained from pieces cut from the same ingot after it had been "pressurized". In addition, they hot forged other sections of the ingot using open dies so that the section was reduced 80% and, in some specimens, 92% and made test pieces from these. Before being tested for mechanical properties, all these pieces were normalized at 1625° F. and air cooled, then reheated to 1525° F. and quenched in oil, and finally tempered at 1000° F. to a hardness of 363 to 388 Brinell. All the pieces were either forged or compressed in the temperature range of 2175 to 2230° F. The ingot was made of S.A.E. 4340 steel. The tensile properties obtained from the tests are listed in the table on p. 124.

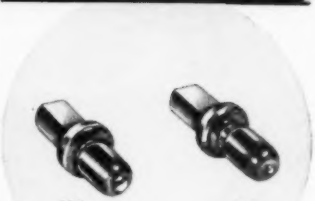
As may be seen by examination of this table, the pressurizing of the cast metal and also the closed-die forging of the rolled metal resulted in improved elongation and reduction of area, particularly in the transverse tests.

The authors point out that hot working an ingot, either by forging or rolling, has the object not only of producing a desired shape but also of altering the structure, breaking up segregates and welding cavities or voids. They believe that in closed-die forging the metal flows in a fashion affected by its internal resistance to deformation and the fractional relationship of steel and die surfaces.

(Continued on page 124)

*Abstracted from "How Forging Acts to Enhance Metal Properties", by E. O. Dixon and E. J. Foley, *Transactions*, American Society of Mechanical Engineers, Vol. 71, 1949, p. 147-152.

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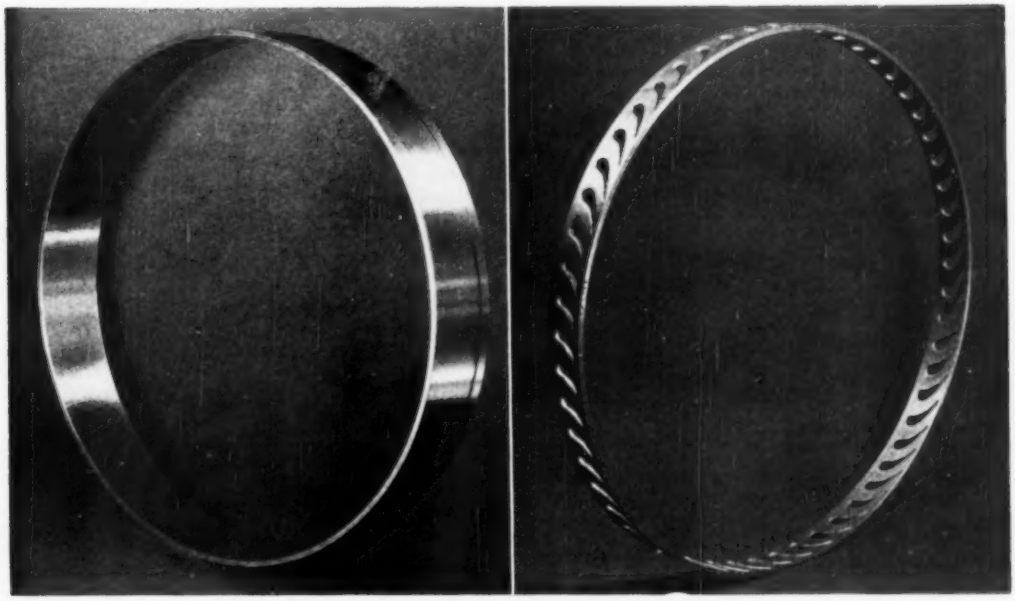
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Effect of Forging

(Continued from page 122)

If the steel fills the die impression, resistance to metal flow increases and a condition approaching complete restraint to metal flow is developed. Excess metal is forced out as flash, cooling quickly and increasing the resistance to further flow. This restraint to metal flow requires increased power to perform the finishing operation and the increased pressure so produced is advantageous in improving the properties of the metal.

The improvement of properties by merely applying pressure at high temperature opens up some interesting possibilities, particularly of closed-die forging billet material of large cross section with less plastic work from the ingot stage. This is of decided importance in view of the great demand for steel forgings produced by the largest drop hammers.

The authors present the work of Aitchison and Johnson showing the improvement in fatigue limit as a result of hot working a steel of approximately S.A.E. 1035 composition. The data presented show an increase in fatigue limit of about 20%, as compared with those obtained with the same steel in the as-cast condition.

The authors indicate that further investigation is needed to show the effect of higher pressures, tested by using hammers of greater rating. They also state that they are studying the fatigue limit of pressurized material.

To many metallurgical engineers in the automotive field, fatigue limit is of prime importance because the great majority of failures are the result of fatigue stressing. There is a question whether higher values of percentage elongation and reduction of area can be utilized to advantage. But there is no question that higher fatigue limits are very much desired, and we shall therefore look forward with great interest to the work which Dixon and Foley have set themselves to accomplish.

W. E. JOMINY

Results of Tensile Tests on Open-Die and Closed-Die Forgings

Reduction in Cross Section	Method of Forging	Longitudinal				Transverse			
		Tensile Strength	0.2% Yield	Elongation in 2 In.	Reduction of Area	Tensile Strength	0.2% Yield	Elongation in 2 In.	Reduction of Area
0	As-cast ingot	173,200 psi.	160,000 psi.	6%	14.6%	169,700 psi.	153,000 psi.	8%	18.4%
0	Closed die, 0% upset	172,500	160,000	11	34.7	181,000	167,500	14	42.2
80%	Open die	184,000	170,000	16	50.8	181,000	174,500	10	22.7
92	Open die	180,000	170,000	15	49.2	181,500	175,500	9	20.6
92	Closed die, 20% upset	175,700	161,500	16	50.6	173,500	163,000	10	36.7

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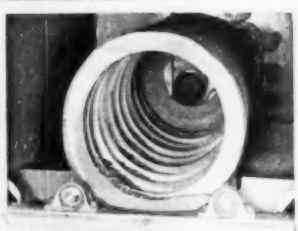
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PHYSICAL AND THERMAL PROPERTIES

Melting point	2675° ± 20°
Molecular volume	21.50
Heat of formation	264K cals/mol
Specific Gravity	5.5-6.0
Index of refraction	2.13-2.21+
Moh's hardness	6.5
Mean specific heat (20°-1000°C)	0.16
Thermal conductivity . app. 0.0089 cal/cm²/cm/°C/sec.	
Thermal expansion (mean reversible 20°-1000°)	6.6x10-⁶/°C
Coeff. of expansion (fused zirconia)	0.00000084
Compressive strength . . . . 20°C	298,680 psi
500°C	237,570 psi
1000°C	170,680 psi
1500°C	2,840 psi

ELECTRICAL PROPERTIES

Resistivity ohm-cm at . . . . 340°C	2.1x10⁶
700°C	2.3x10⁴
1200°C	1.2x10³ohm/cm³
Dielectric Constant	20.

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Mosaic Structure*

THE term "mosaic structure" was coined by Professor Ewald in 1917. The phenomena which led to it consisted in large discrepancies between the intensities of X-ray reflections as calculated and as observed. The observation was made first by Darwin and Moseley in 1913 and 1914.

The idea of "blocks" of which the metallic grain consists was accepted without much resistance long before their actual existence could be proved. An extensive study of the question began only in the last 15 years.

Three avenues of approach existed: *(a)* the continuation and perfection of X-ray methods, *(b)* micrography, and *(c)* mechanical and physical properties.

Assuming that the mosaic blocks differed in their orientation, the study of the dispersion of parallel polychromatic X-rays seemed to be most promising. But the dispersions in question were of the order of a few seconds of arc and the old method would not permit the measurement of dispersions less than 10 min. Guinier and Tennevin improved the technique until angles of 15 sec. could be measured. The introduction of the double spectrometer made it possible to note dispersions of 1 sec. It was found, however, that a total dispersion of 20 sec. without sharp breaks covered volume elements of more than 1 mm. in diameter. This permitted the postulation of subgrains at least 10 or even 100 microns across, in aluminum as well as in diamond crystals. Last year Guinier and Lacombe offered the idea of polygonic subcrystals in cold worked metals.

German scientists (Kochendoerfer and Zehender) used the method of analyzing the coherence of X-ray diffractions. They estimated the mosaic blocks to be 0.2 to 1 micron across, but their results were considered too uncertain.

The study of physical characteristics has so far brought only hypotheses. Enormous differences between theoretical cohesion forces and technical strengths indicated long ago that there must be "imperfections" in crystals, but no rational theory of their size and shape could be established.

Really valid results were obtained only with microscopy; the authors mention veining, polygonal shadows crossing grain boundaries, differences in corrosion figures within the individual grains, and so on. Apparently the most striking results were obtained in the study of the growth of metals from vapors, undisturbed melts and by electrolysis. In all such solids the crystals were found to be built up of platelets about one micron thick. In worked and annealed metals the disturbances are too great to permit observation of such platelets.

The problem of mosaic crystals is still far from a clear presentation, to say nothing of a satisfactory solution. It should be studied far more diligently, for the yield and tensile strengths of metals probably depend on the forces between the mosaic blocks within grains.

*Abstracted from "A Report on the Symposium on Mosaic Structure of Metals", by C. Crussard and A. Guinier, *Revue de Métallurgie*, Vol. 46, 1949, p. 61-71. Twelve French physicists took part in the symposium and 67 references are cited in the report.

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Plasticity of Intermetallic Phases*

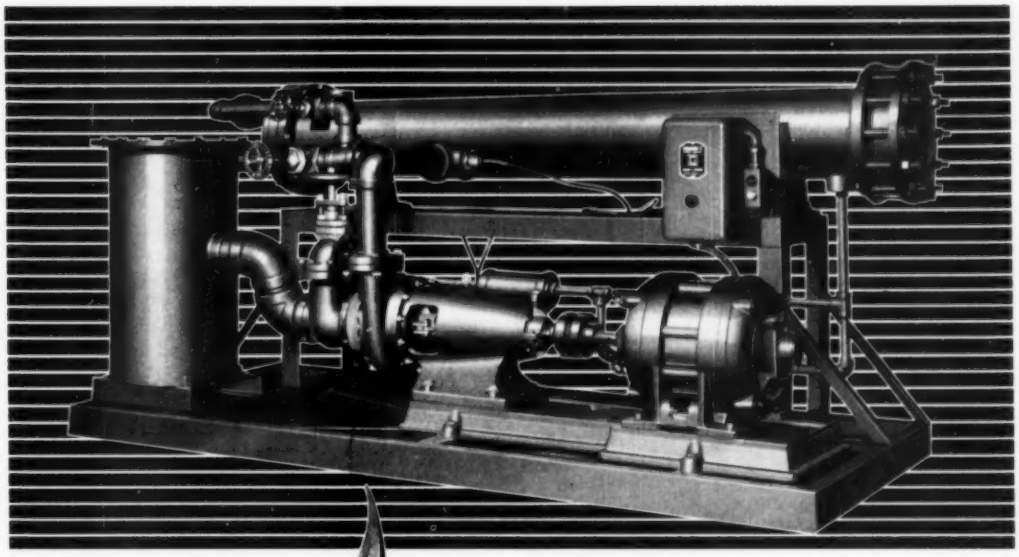
INTERMEDIATE PHASES of either fixed or variable composition are formed in many alloy systems. These so-called intermetallic compounds usually have properties different from the pure metals of which they are composed. For example, their crystal structures are generally complex, and these phases are almost always brittle at room temperature. Although small amounts of intermetallic compounds, such as $CuAl_2$, are used in commercial alloys, it is generally considered that the pure intermetallic phases are not of commercial interest.

In the author's study of the relation of mechanical properties and the phase diagram, deformed specimens of intermetallic phases were needed. He decided to take advantage of the property of metallic substances to soften on heating. It was found that intermetallic phases heated to temperatures near the melting temperature and deformed at low speed are plastic.

The following three examples confirm the high plasticity of intermetallic phases.

1. The compounds MgZn, $MgZn_2$ and $MgZn_5$ are brittle *(To p. 128)*

*Abstracted from "Plasticity of Intermetallic Phases", by E. M. Savitskii, *Doklady Akad. Nauk S.S.S.R.*, Vol. 62, 1948, p. 349-351. (In Russian.)



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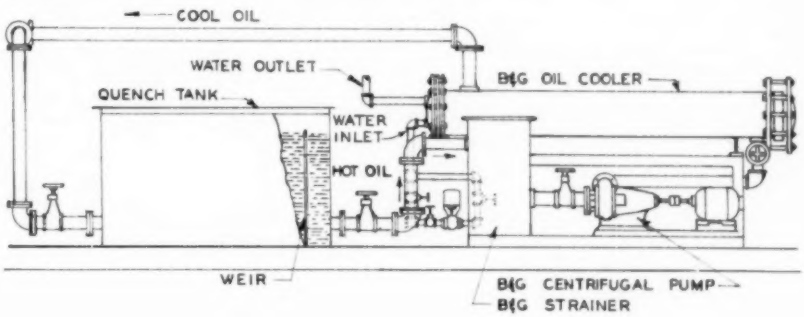


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Plasticity of Intermetallic Phases

(*Cont. from p. 126*) at room temperature. Cast bars of each of these compositions were deformed 80 or 90% without sign of rupture at high temperatures by pressing through a cylindrical steel die.

2. The β and γ phases in the magnesium-aluminum system are completely brittle at room temperature. Under suitable temperature-velocity conditions of deformation, bars of these phases were also obtained. In addition, these bars were then reduced 80 or 90% at 400° C. by upsetting in one operation without rupture.

3. The β phase in the copper-zinc system softens more on heating than does the α solid solution.

Several conclusions can be drawn concerning the deformability of intermetallic phases: *(a)* Intermetallic phases can be worked by means of pressure, especially at higher temperatures; *(b)* heating a complex industrial alloy causes a redistribution of the hardness and strength of its phases, and the hardest phase at room temperature may be the softest at high temperatures; *(c)* intermetallic phases of the γ type soften less on heating than do β phases, where β is the phase adjacent to the α solution.

The sharp increase in plasticity with temperature cannot be explained entirely by the increase in the amplitude of thermal vibration of the atoms. Rather, some change in the crystal (new slip systems, new type of chemical bond, or other change) must be assumed.

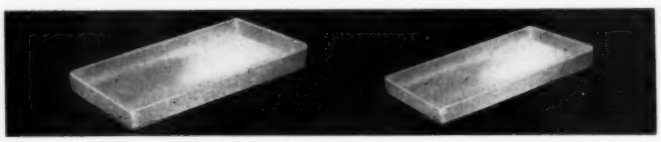
All-Basic Roofs*

THE authors described petrographic and chemical studies of some Rytex-type bricks taken from all-basic roofs of openhearth furnaces. The bricks were typical unfired, metal-encased compositions and were studied after 324 and 14 heats in crowns and 50 heats in an end wall.

Chemical analysis of the 324-heat bricks showed that the silica content was highest in a zone just behind the hot face (*To p. 130*)

*Abstracted from "The Chemistry of Chrome-Magnesite Roof Brick During Service", by T. F. Berry, W. C. Allen and R. B. Snow. Paper presented at the 51st annual convention of the American Ceramic Society, April 1949.

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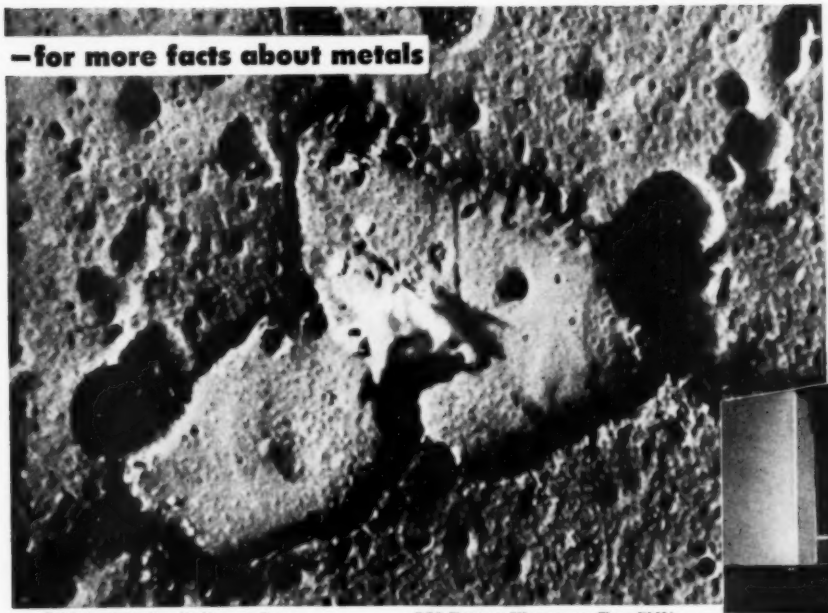
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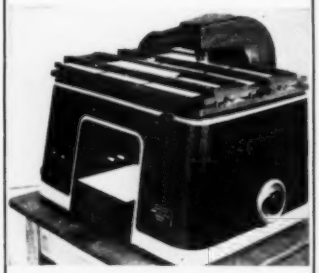
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All-Basic Roofs

(Cont. from p. 128) where the silicate bond had apparently migrated from the hot end. The magnesia content varied from 23 to 44% from hot to cold ends. In the same direction: The alumina varied from 9.06 to 18.8%, the chrome was present in amounts between 13.22 and 20.30%, and the iron oxide varied from 44.34 to 8.86% in the middle of the brick and remained about 9% in the rest of the colder portion of the brick. In addition, it was found that MnO and CaO were higher in the hot face than in the rest of the brick.

The dimensions of the brick had also changed considerably. In the first two hot zones only about 65% of the original volume was still present. The next two zones were about 85% retained and the outer two zones showed 95 and 100% respectively. Much of the loss is apparently caused by growth of the steel encasement on each brick, which oxidizes and grows to three times its original thickness. On the entire roof, this growth amounts to 8 in., which must be accommodated by the springs or it will cause a spalling type of failure from compression.

Petrographic studies of the bricks were in good agreement with the chemical analysis mentioned above. In the hot face a thin peely structure was found to contain large periclase and complex spinel crystals, hematite, and about 75% iron oxide. The authors consider the primary cause of the peeling to be the large periclase crystals and that an alumina addition would help to prevent this by forming spinel. In general, the picking up of iron is the primary cause of brick failures. Some magnesia-ferrite precipitate was found, even in the cooler parts of the brick. The iron is considered to be tied in with magnesia, silica and calcia, sometimes as FeO but most commonly as Fe_2O_3. The ratio between these two oxides of iron ran as high as 1 to 150 respectively.

The bonds within and between the bricks were also discussed. Within the brick the chemical bond at the cold end remains sufficiently strong while the ceramic bond at the hot end is being developed at high temperatures. The worst conditions were found in the 324-heat bricks; but even in the bricks used for shorter periods the same zones were found, to a slighter degree.

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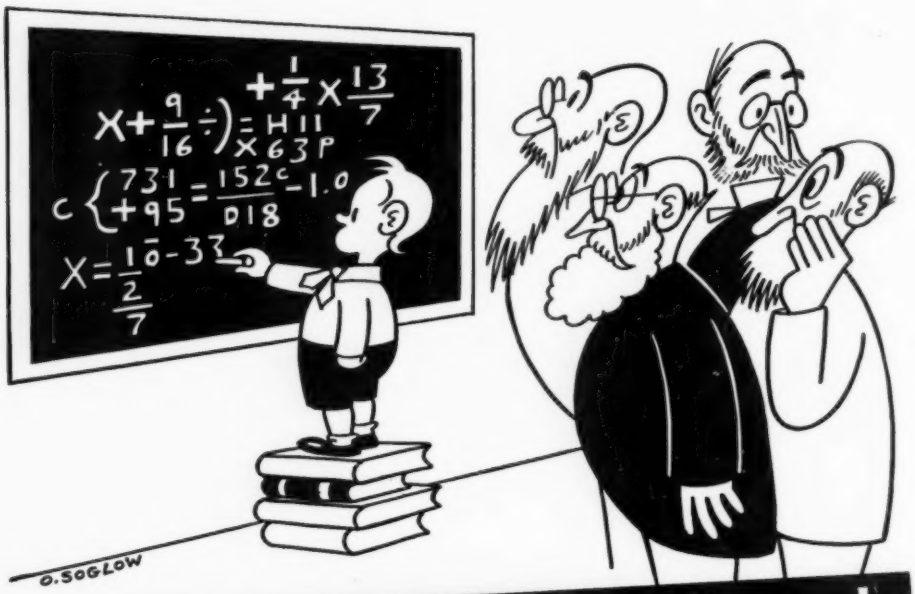
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You'll be surprised at these figures!

- 80 million Americans own $48 billion of U. S. Savings Bonds.
- 20,000 of the nation's 38,000 firms employing 100 or more persons are operating Payroll Savings Plans.
- 7,500,000 workers are buying an individual average of $20 of Bonds per month.
- For the year 1948, sales of Series E Bonds exceeded redemptions by $495,148,000. The net figure for all Series after redemptions and maturities was $2,151,140,000.

What does all this mean to you? Well, it means first of all that your Treasury Department is successful in its program of increasing the nation's economic security by spreading the national debt. Secondly it means that most of the nation's business leaders recognize the value of the Payroll Savings Plan sufficiently to promote it within their companies.

For example...

To give you some idea of the Plan's growing popularity: 86,384 employees of a prominent electrical manufacturing company were investing in Bonds at the rate of $30,005,270 as of the end of 1948. This is a gain of nearly 100% over 1947, when 45,000 employees participated in that company. The treasurer of a well-known shoe company reported that, of his concern's 19,060 employees, 9,240 were in the Plan and had invested $146,807.32 in Bonds via deductions during the preceding month.

Why promote it?

We all know how buying Bonds builds an individual's future security. But there are *company* benefits too! Nation-wide experience shows that Payroll Savings increases each participating employee's peace of mind—makes him a more contented, more productive worker. It reduces absenteeism, lowers accident rates, increases output, and improves employee-employer relations.

It's easy to boost participation

1. See that a top management man sponsors the Plan.

2. Secure the help of the employee organizations in promoting it.

3. Adequately use posters and leaflets and run stories and editorials in company publications to inform employees of the Plan's benefits to them.

4. Make a person-to-person canvass, once a year, to sign up participants.

These first four steps should win you 40-60% participation. Normal employee turnover necessitates one more step:

5. Urge each new employee, at the time he is hired, to sign up.

Nation-wide experience indicates that 50% of your employees can be persuaded to join—without high-pressure selling. All the help you need is available from your State Director, U. S. Treasury Department, Savings Bond Division.

The Treasury Department acknowledges with appreciation the publication of this message by

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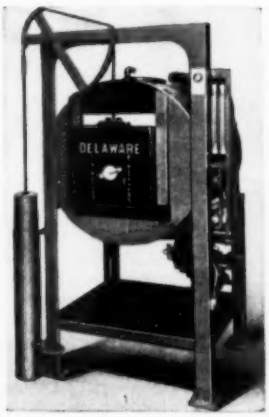
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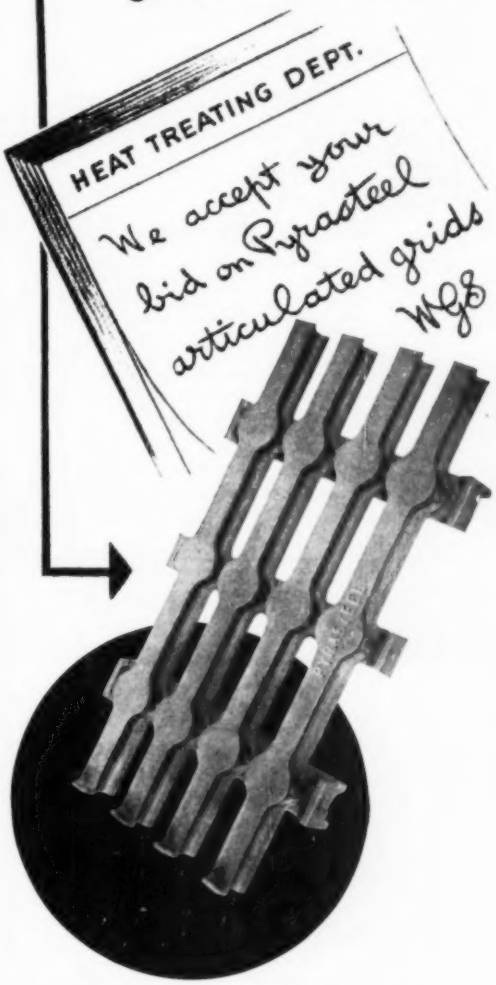
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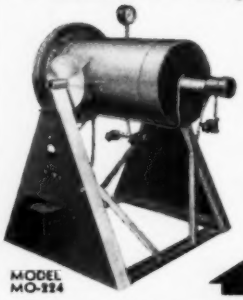
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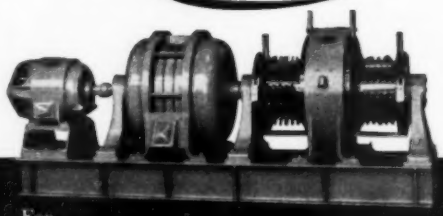
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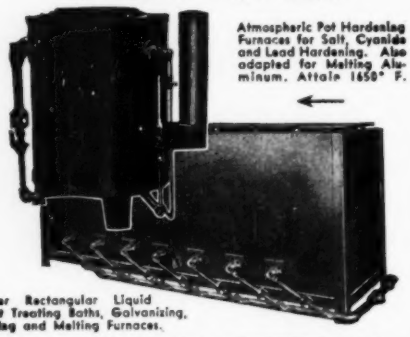
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Truman M Pease

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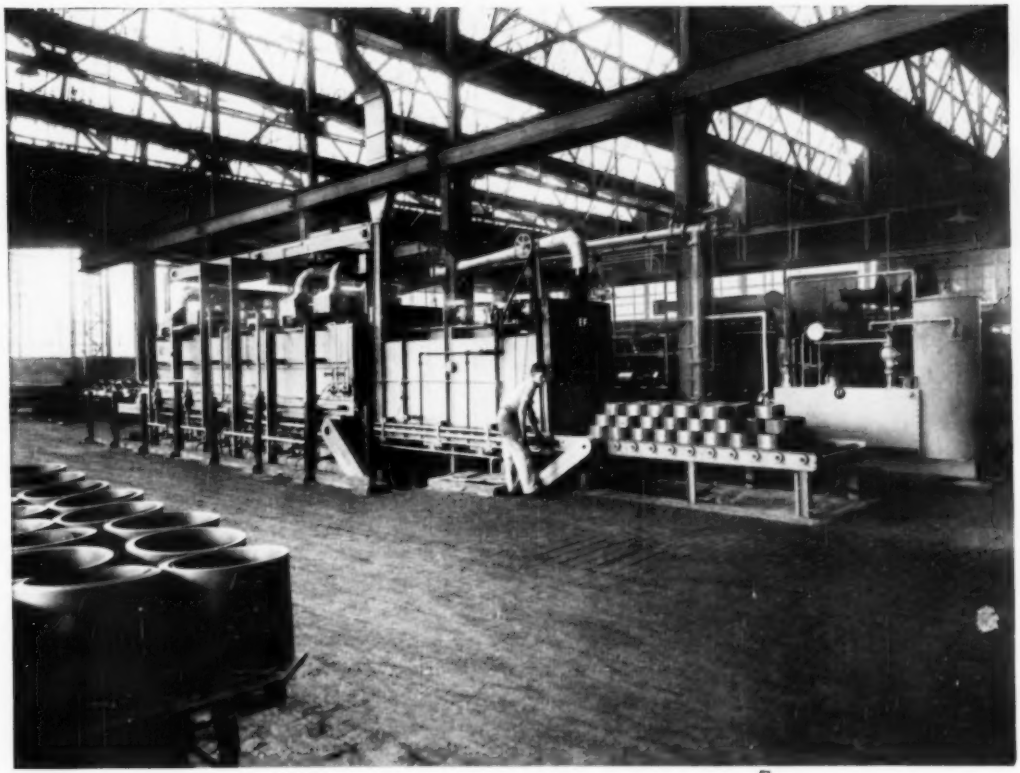
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